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SURGERY OF SUBSTERNAL AND INTRATHORACIC GOITERS *

J. DEJ. PEMBERTON, M.D.
ROCHESTER, MINN.

In denoting the presence of a prolongation or of the enlargement of the entire thyroid gland behind the sternum or within the thoracic cavity, the terms "substernal" and "intrathoracic" have been used synonymously. In this article, the term intrathoracic goiter will be limited to those growths of the thyroid in which the major portion of the tumor lies within the thorax. This does not necessarily imply that the greater portion of the entire thyroid gland lies concealed, for obviously the greater portion of the goiter may be cervical and confined to one lobe, while there may be a large, but smaller, growth in the other lobe entirely within the cavity of the chest. All other tumors of the thyroid whose inferior projection, varying in depth below the sternal border from 1.25 cm. to 7.5 cm., and equivalent to less than one half of the growth, are classed as substernal goiters.

MECHANISM OF PRODUCTION

Occasionally in emphysematous patients with short necks the diffuse hyperplastic gland may lie partially behind the sternum, yet its downward projection is usually limited to 1.25 cm. or less, and offers no additional difficulty in its removal. This type will not be considered in this discussion.

The large substernal and intrathoracic growths consist of the simple benign or malignant adenomas, either cystic or solid, and occasionally a diffuse colloid projection. Various causes for the descent of these tumors have been suggested, namely, the pressure exerted by the depressor muscles of the hyoid and the sternomastoid (Lahey), the

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1. Lahey, F. H.: Intrathoracic Goiter, Boston M. & S. J. **176**:341 (March 8) 1917; Diagnosis and Management of Intrathoracic Goiters, J. A. M. A. **75**:163-166 (July 17) 1920.

influence of swallowing, ptosis of the larynx, gravity, flexion and extension of the head, and the development of an adenoma in a normally low thyroid, which has been congenitally displaced by traction of the thymus during its embryologic development. All of these may be contributing influences. When the anatomy of the region is borne in mind, it seems natural that the extension of growths developed in the lower poles should be downward behind the sternum. The thyroid is only relatively fixed, since it follows the movements of the trachea in deglutition. It is bound firmly to the trachea by connective tissue attachments, and to the larynx and hyoid bone by median bands,

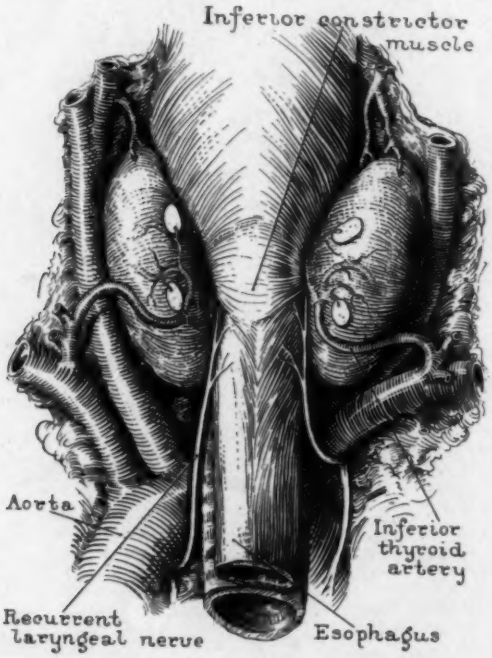

Fig. 1.—Position of recurrent laryngeal nerves and inferior thyroid arteries, viewed posteriorly.

the suspensory ligaments, and it is partly anchored at the points of entrance of the two main arteries. The superior thyroid artery joins the gland at its superior pole, but the inferior thyroid artery enters the capsule on the posterior surface near its mesial border, slightly below a point half way between the superior and inferior poles (Fig. 1). As the inferior thyroid artery ascends in the neck behind the carotid sheath, it is snugly bound behind the prevertebral layer of the deep cervical fascia, from which it emerges a short distance before joining the gland. It will readily be seen that this affords a good anchorage for this portion of the lobe. However, the part of the gland below

this level, amounting to nearly half a lobe, has no firm attachments to the neighboring structures. The inferior thyroid veins leaving the gland at its inferior pole offer only a meager support. The thyroid is loosely encased between the middle and the prevertebral layers of the deep cervical fascia, both of which extend down into the mediastinum. It can be readily appreciated that an adenoma developing in this part of the lobe below the level of the entrance of the inferior thyroid artery will extend downward between the fascial planes in the direction of least resistance. Anteriorly and laterally its extension is resisted by the overlying muscles, especially the sternohyoid, sternothyroid, omohyoid, and the sternomastoid; posteriorly, by the muscles covering the spine, and superiorly, by the firm attachment of the upper part of the lobe to the trachea and to the inferior thyroid artery. Inferiorly, it is separated from the thorax by thin areolar tissue only.

The influences of deep respiratory movements of the thorax in coughing, straining, and the like, play an equally important rôle in the mechanism of production of substernal and intrathoracic goiters. The shape of the thoracic cage is that of an irregular truncated cone. Its reniform inlet formed by an imaginary plane slanting downward and forward from the top of the first thoracic vertebra to the sternum is the narrowest part, the anteroposterior diameter measuring 5.5 cm. and the transverse diameter 10.5 cm. (Woolsey).[2] In forced inspiration the sternum is raised, thus increasing the anteroposterior diameter; since the ribs swing upward and outward, the transverse diameter is likewise increased (Piersol).[3] Also, in deep inspiration, because of the greatly increased capacity of the thorax, a negative pressure is created within the chest which tends to drag the goiter downward. The effect of this can be tested by observing a small cervical goiter entirely disappear behind the sternum when the patient takes a deep breath.

As the adenoma enlarges, the direction of its growth continues in the line of least resistance, that is, downward into the cavity of the chest, where it is obstructed only by the bony walls of the cage. When the condition develops in the young, a deformity of the chest wall may occur (Fig. 2). The shape of the larger tumors is molded by these boundaries, resulting in the characteristic flask or pear shape, the small end corresponding to the constricted inlet. As long as the size of the intrathoracic portion remains less than that of the inlet, the tumor may be forced, partially or completely, up into the neck by coughing or swallowing, which accounts for the occasional so-called

2. Woolsey, G.: Applied Surgical Anatomy, Philadelphia, Lea and Febiger, 1908, p. 228.

3. Piersol, G. A.: Human Anatomy, Ed. 5, Philadelphia, J. B. Lippincott Company, 1916, p. 166.

diving goiter, *goître plongeant* of Fodéré.[4] When the intrathoracic goiter has enlarged so that it cannot be forced up through the narrow strait, one of two things may happen. As the intrathoracic portion is relatively fixed and as the cervical part of the gland continues to follow the movements of the trachea, intermittent traction is exerted at the juncture, and either this connecting portion becomes more attenuated, resulting in a partial or complete detachment of the intra-

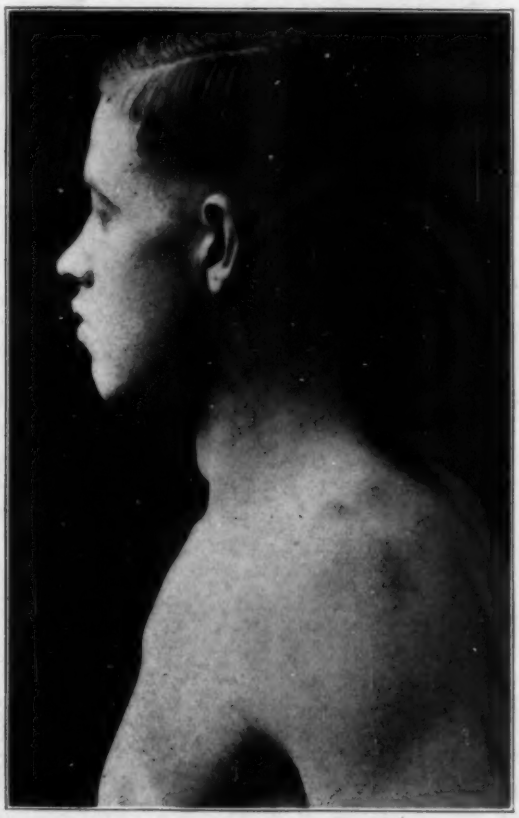

Fig. 2 (Case 297878).—Deformity of chest in case of large intrathoracic goiter.

thoracic portion, or the cervical lobe is dragged down into the chest. It appears that a great many of the accessory intrathoracic goiters are developed in this manner from the cervical thyroid rather than from the enlargement of the so-called aberrant thyroid tissue. Analogous growths are not infrequently found in the neck when adenomas lie in the posterior cervical triangle joined to the original goiter by only

4. Fodéré, quoted by Sharpe, N. W.: Report and Analysis of a Goiter with Marked Intrathoracic Extension, Interstate M. J. **18**:314-325, 1911.

a small band of connective tissue, or completely detached, living a parasitic existence. In this series, the intrathoracic tumor was detached from the cervical goiter in seven patients.

INCIDENCE

Within a period of approximately three and one-half years, from Jan. 1, 1917, to June 6, 1920, 4,006 thyroidectomies were performed in the Mayo Clinic for simple colloid and adenomatous goiters. Five hundred and forty-two (13.5 per cent.) were found at operation to be substernal, and twenty-five (0.6 per cent.) of these were classified as intrathoracic.

The duration of the goiter ranged from two months to forty-eight years, averaging eighteen and one-half years. Seven patients had no knowledge of the presence of a goiter. The oldest patient was 71 years of age, the youngest 15, and the average age was 46.11 years.

TABLE 1.—Situation of Substernal Projection

Situation	Cases
Right lobe	158
Left lobe	299
Both lobes	66
Isthmus	8
Not noted	11
Total	542

TABLE 2.—Depth of Goiter

Depth	Cases
1.25 cm. to 2.5 cm	300
3.75 cm. to 5.0 cm	170
6.25 cm. to 7.5 cm	60
8.75 cm. to 12.5 cm	12

The influence of sex does not apparently play an important rôle in the total incidence of substernal goiter. While in the male, heavier neck muscles develop, in the female this additional influence is offset by the fact that the upper aperture is wider, and that thoracic rather than abdominal breathing is the rule. In this series, substernal or intrathoracic goiter occurred in 82 males (13.5 per cent.) and in 460 females, or 1 male to every 5.6 females. During the same period, the ratio of incidence in males and females in all other simple goiters was 469 to 2,295, respectively, or 1 to 6.38. However, of twenty patients between the ages of 15 and 25 with substernal or intrathoracic goiter, six (30.0 per cent.) were males.

There was malignant degeneration in seven goiters.

SYMPTOMS

Substernal and intrathoracic goiters, are, in the greater number of cases, associated with cervical enlargement, and the symptoms from which the patient seeks relief vary from deformity of the neck to a train of symptoms incident to hyperthyroidism, or to the pressure of the tumor on the neighboring structures.

In seventy-two patients of the series, there were no symptoms other than the presence of a tumor. In 128 patients (25.4 per cent.), the goiter was associated with definite hyperthyroidism, evidenced by

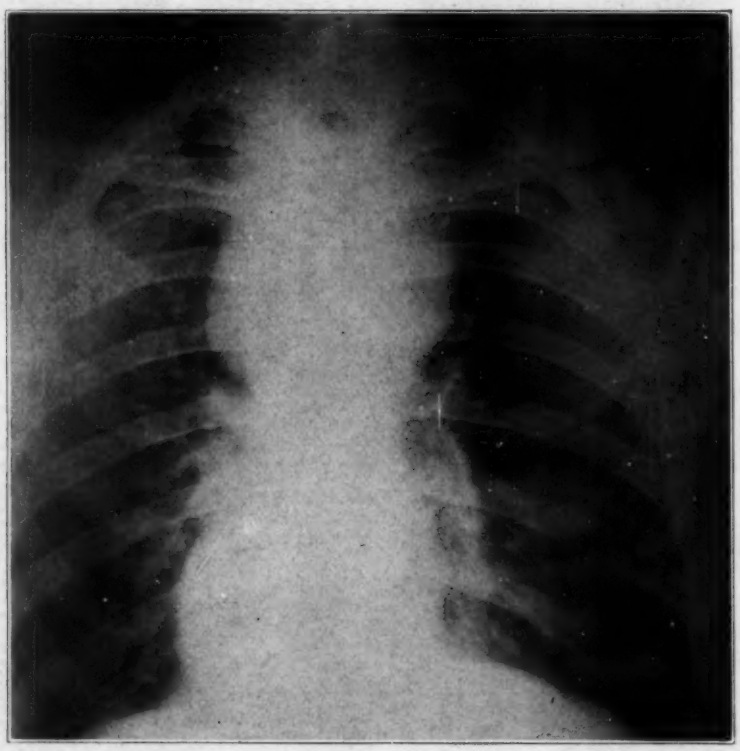

Fig. 3 (Case 297878).—Anteroposterior view of large intrathoracic goiter shown in Figure 2, before operation.

the symptoms and physical examination and corroborated by an increased basal metabolic rate.

The symptoms resulting from the pressure of the substernal tumor vary according to the structure compressed, and the symptoms and their intensity vary not in proportion to the size of the tumor, but to the degree of compression. A small adenoma lying just within the inlet, in front of or behind the trachea, may produce marked dyspnea or choking spells, while a huge, completely intrathoracic tumor

may be wholly without pressure symptoms. This is illustrated by the subjoined case history.

History (Case 297878).—A man, aged 21, was admitted to the Mayo Clinic, Nov. 25, 1919, having been discharged from the army a year before on account of tachycardia. The patient stated that he had always enjoyed good health and had been an active athlete. Because he did not have so much "pep" as formerly, he consulted a physician a few weeks prior to his admission to the Clinic. A diagnosis of exophthalmic goiter in a substernal thyroid was made by his family physician. There was no dyspnea, palpitation, or other complaint.

Fig. 4 (Case 297878).—Lateral view of large intrathoracic goiter shown in Figure 2, before operation.

The patient said that his chest had always been prominent, probably more than usually prominent for the last six months (Fig. 2). He had not lost weight.

Examination.—No enlargement in the cervical region was found; but there was an area of dulness which extended downward 5 cm. on each side of the midsternal line. The systolic blood pressure was 164, the diastolic 84, and the pulse 120. The urine was normal. The basal metabolic rate taken on three different occasions was +33, +29 and +23. A roentgenogram revealed a bilateral mediastinal tumor, and the fluoroscopic examination revealed a mediastinal mass atypical for substernal goiter (Figs. 3 and 4). There was no

exophthalmos. A diagnosis of mild hyperthyroidism in an intrathoracic goiter was made.

Operation and Results.—A partial thyroidectomy, resection of the left lobe and division of the isthmus, was performed, Dec. 12, 1919, for a single degenerated colloidal adenoma in a substernal goiter. A huge substernal goiter, about 12 or 15 cm. in diameter, lay in front of the trachea, resting on the base of the heart. It originated in the left lobe and probably the isthmus, drawing the isthmus and superior pole of the left lobe down to the base of the neck. The curved collar incision was prolonged downward, with the idea

Fig. 5 (Case 297878).—Patient shown in Figure 2, after operation.

of splitting the sternum if necessary. The gland was ruptured to reduce its volume before bringing it out of the chest cavity. Tissue amounting to one fourth of a normal sized lobe was preserved on the left side of the trachea.

The patient's postoperative convalescence was normal (Figs. 5 and 6). The metabolic rate, Dec. 24, 1919, was +9. December 30, the blood pressure was 116 systolic, and 74 diastolic; the pulse rate was 78.

The more snugly the tumor is wedged into the thoracic aperture, the more pronounced are the symptoms. The retrosternal tumor lies

in close relation to the trachea, esophagus, common carotid artery, internal jugular vein, pneumogastric, sympathetic, phrenic, and recurrent laryngeal nerves, and as it descends, it is in close relation to the innominate and subclavian vessels, the thoracic duct, lungs, bronchi, the arch of the aorta, and the pericardium (Fig. 7). On account of the capaciousness of the thoracic cavity and the relative movability of its contents, the completely intrathoracic goiter may be without symptoms, since all the structures can be displaced without being

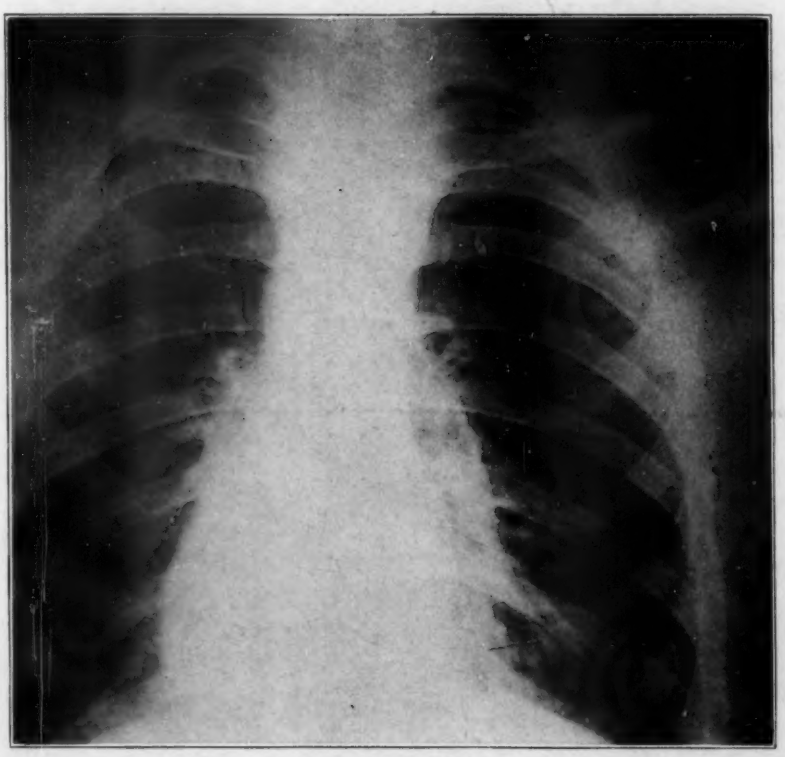

Fig. 6 (Case 297878).—Anteroposterior view of chest of patient shown in Figures 3 and 4, after operation.

actually compressed. The recurrent laryngeal nerve is an exception, as displacement of the large arterial trunks may exert traction resulting in its partial or total paralysis. However, any structure that passes through the upper thoracic aperture may be compressed by the goiter, with resulting symptoms. Pain is practically never present unless the tumor is malignant, but a sense of pressure or fulness is very frequent. Symptoms arising from pressure on the trachea, the recurrent laryngeal and the internal jugular vein are the most frequent.

Definite tracheal deformity was noted in 163 patients (30 per cent.) of the series. The tumor may lie anterior, posterior, or to the side of the trachea, and the symptoms, if any, are varying degrees of dyspnea, such as rasping breathing with inspiratory stridor, and choking and coughing spells. Sudden muscular exertion or extension or flexion of the head may cause the tumor to become wedged in the inlet, resulting in spells of obstructive breathing, with choking and coughing. Dilated veins in the neck and on the chest wall were noted in fifty-eight patients (10.7 per cent.), (Figs. 8, 9 and 10). Laryngeal

Fig. 7 (Case 333997).—Huge intrathoracic goiter filling the right upper portion of the chest.

examinations were recorded for 452 patients, and in forty-five (10 per cent.) a partial or complete paralysis of one or both cords was noted, although hoarseness was recorded in only twenty-nine patients.

DIAGNOSIS

In the presence of a cervical enlargement, a substernal or intrathoracic goiter can frequently be diagnosed by palpation. In most cervical goiters, the inferior pole of the lobe is well outlined when

the patient swallows or coughs. If the limit of the lower pole cannot be palpated, a substernal projection is suspected. If the neck is not enlarged, often a tumor may be felt or seen above the clavicle or sternum when the patient swallows or coughs. With the larger growths, percussion may reveal dulness. Many have emphasized the importance of the sudden disappearance of a cervical goiter with or without the appearance of marked obstructive symp-

Fig. 8 (Case 320327).—Huge intrathoracic goiter producing marked obstruction and dilatation of veins over neck and chest.

toms. In only seven patients in this group was an appreciable diminution in the size of the goiter noted, and in three of these the history was indefinite. Only one patient gave a definite history of disappearance of the gland, with the production of obstructive respiratory symptoms. As the shadow of a small, retrosternal goiter may not be discerned in the roentgenogram the final preoperative diagnosis rests on the fluoroscopic examination.

OPERATIVE TECHNIC

In patients with large substernal goiters, or in those who have any obstructive dyspnea, local anesthesia should be employed. Not infrequently when the patient is under the influence of a general anesthetic serious respiratory obstruction is encountered, either during the elevation of the tumor or even before the incision in the skin has been made. In many of these patients, the pressure of the goiter on the trachea has so embarrassed breathing that the accessory muscles of respiration have been brought into play, especially the sternomas-

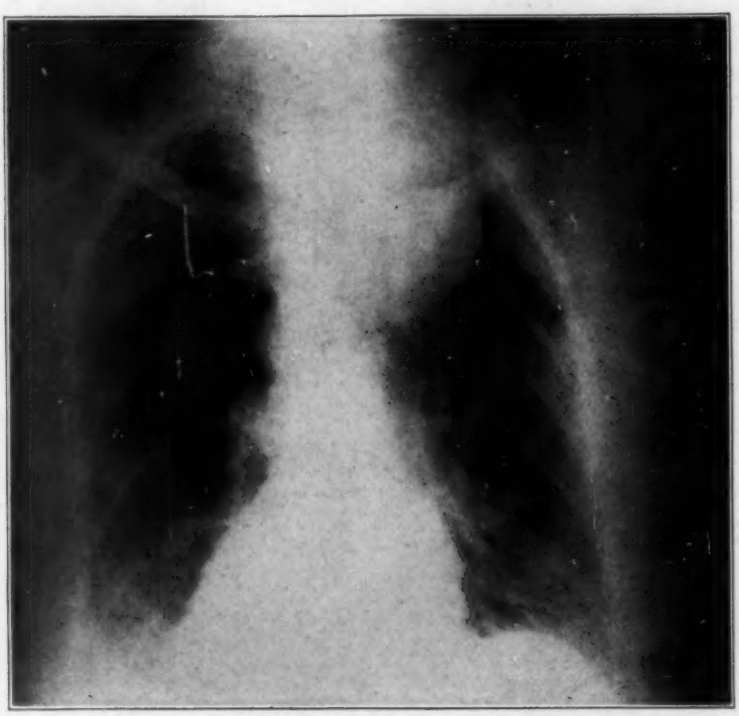

Fig. 9 (Case 320327).—Goiter shown in Figure 8.

toids, trapezius, pectoralis major and minor, rhomboideus major and minor, and the erector spinae. Under a general anesthetic the assistance of these muscles is lost, and respiratory movement may be extremely difficult or impossible. In such cases the operator must either hastily elevate the tumor, or perform a tracheotomy. If possible both procedures should be avoided. When the goiter is raised hastily, frequently the thyroid veins, and sometimes the inferior thyroid artery, are torn. Attempts to clamp these may result in the injury of important neighboring structures, such as the internal jugular vein

and the recurrent laryngeal nerve. The technic of the operation was recently described by Judd.[5]

The thyroid is approached through the usual low transverse incision, reflecting upward a flap of skin and the platysma muscle. It is essential that all the bleeding vessels are caught and tied before the goiter is approached; otherwise the field of operation may be partially obstructed by the presence of hemostats. The goiter is exposed by dividing the fascia in the midline between the two sterno-

Fig. 10 (Case 320327).—Patient shown in Figure 8, after operation.

hyoids. These muscles are divided between clamps, including a part of the sternocleidomastoid if necessary for better exposure.

As tracheal obstruction may be encountered at any stage of the operation, the surgeon should at once locate the trachea; its position may be greatly changed from the normal, owing to the pressure of the tumor. The first step in removing the intrathoracic goiter is free-

5. Judd, E. S.: Intrathoracic Goiter, Internat. Clin. **1**:149, 1920.

ing the superior pole by dividing the superior thyroid vessels between double clamps (Fig. 11). These vessels are tied immediately, in order to rid the operative field of the presence of the forceps, which, if left, might be pulled off during the course of the operation, resulting in troublesome bleeding.

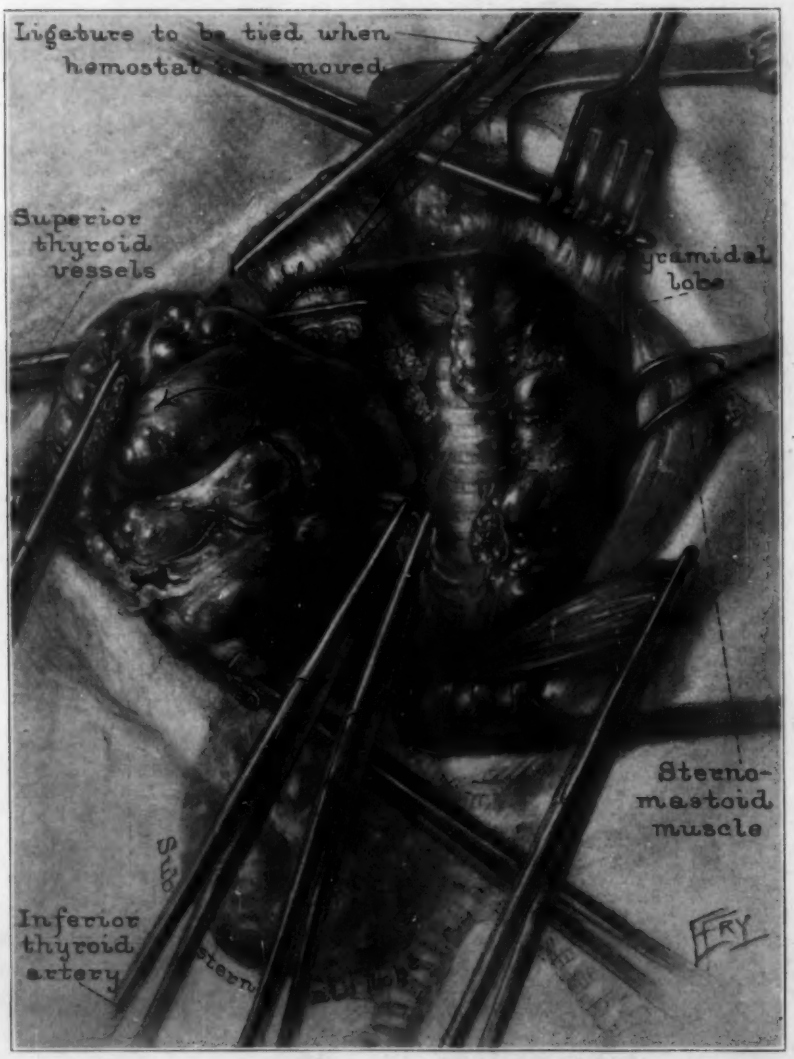

Fig. 11.—Right superior pole of gland free and isthmus divided. Mesial branch of inferior thyroid artery before it is divided.

The middle thyroid vein, which drains a rich plexus of veins beneath the capsule, emerges from the lateral surface of the gland

and enters directly into the internal jugular. This is divided and tied immediately.

The isthmus is then divided and the lobe freed from its attachment to the trachea. By traction on the tumor in a forward and slightly downward direction, the goiter may be resected from above

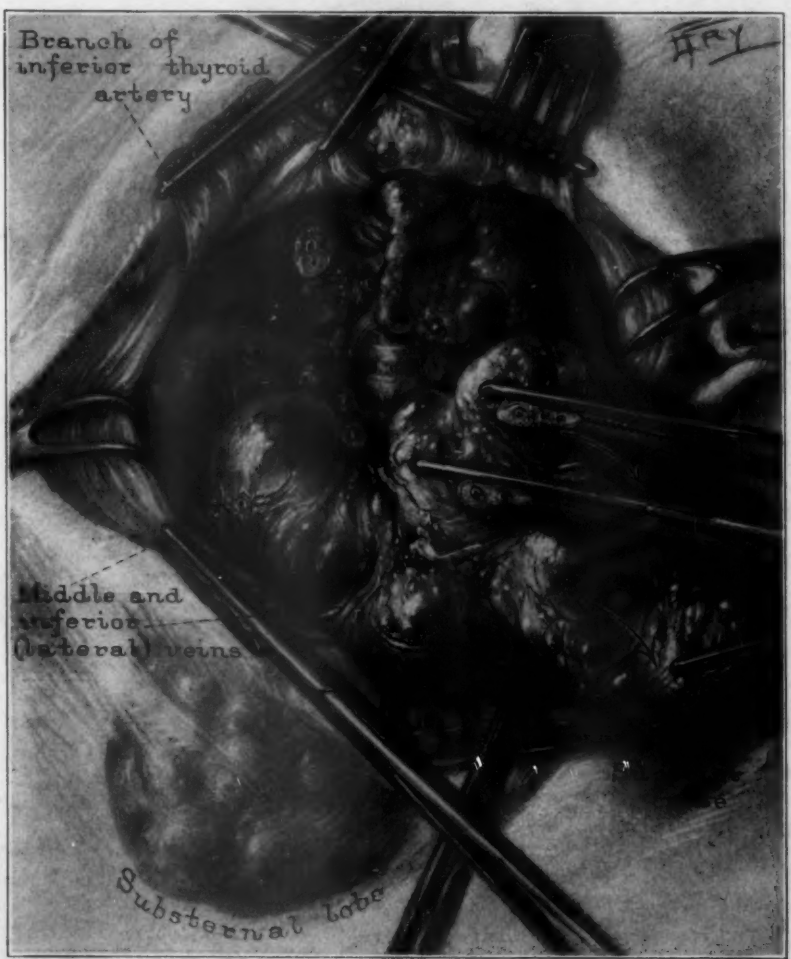

Fig. 12.—Superior thyroid pole drawn downward and inward. Both branches of the inferior thyroid artery have been divided and ligated before the substernal tumor is elevated.

downward, leaving the posterior capsule. As the inferior thyroid artery enters the gland near the middle of the lobe and remains partly in the neck in practically all substernal goiters, its branches can be clamped and severed before the substernal projection is raised

(Fig. 12). If an attempt is made to pry up the intrathoracic portion before dividing the inferior thyroid artery, there is always danger of tearing this vessel.

The only unclamped vessels remaining are the inferior thyroid veins (often two) which leave the gland at its inferior pole. These will usually be found entirely within the thorax. By traction on the cervi-

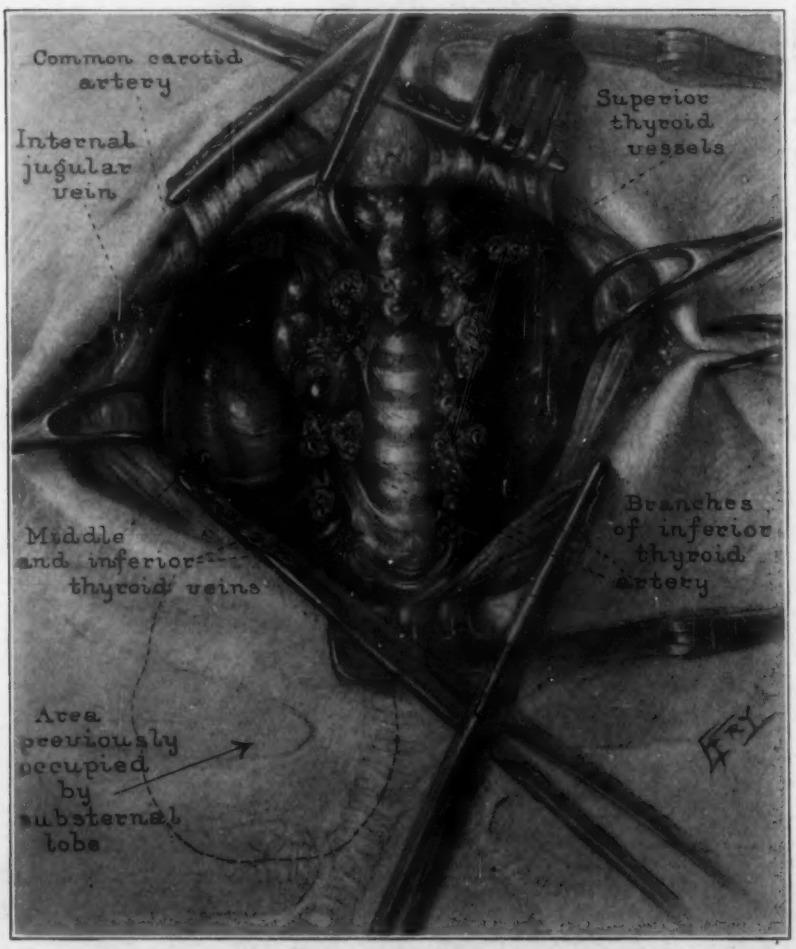
Common carotid artery
Internal jugular vein
Superior thyroid vessels
Branches of inferior thyroid artery
Middle and inferior thyroid veins
Area previously occupied by substernal lobe

Fig. 13.—Operation completed except suture of divided muscles and closure of skin incision.

cal portion of the goiter, the intrathoracic projection can be elevated and the inferior thyroid veins clamped as they come into view (Fig. 13).

Difficulty may be experienced in elevating the tumor from the thorax. If it cannot be elevated easily, one of two procedures may

be followed, namely, removal by morcellation or longitudinal division of the sternum in order to increase the diameter of the thoracic aperture, as suggested by Lilienthal.[6] If the inferior thyroid artery can be secured first, removal by morcellation may be accomplished with safety. However, if the entire thyroid gland is within the thorax and the inferior thyroid artery cannot be secured, it is probable that division of the sternum may be necessary for the removal of the tumor, although this procedure will be undertaken with definite additional risk.

If a large cervical tumor is also present on the side opposite the intrathoracic projection, it is often well to resect this tumor first as better exposure will be obtained for attacking the substernal tumor.

In every thyroidectomy, an examination of both lobes should be made as a matter of routine, since often very large tumors may be concealed behind the sternomastoid, possibly behind the trachea or beneath the sternum. In our experience the "recurrences" of simple adenomatous growths have been due to failure to remove all adenomatous tissue at the first operation. In this series there were seventeen patients who had had previous operations for the removal of a portion of the gland. Three of these had had two operations. In 448 patients, the goiter involved both lobes, and bilateral resections were required; in thirty-five patients, the right lobe and isthmus were removed, and in fifty-eight patients, the left lobe and isthmus.

The intrathoracic tumor, unless malignant, is definitely encased within the capsule of the thyroid. It is separated from the intrathoracic organs by an additional layer of fascia to which the tumor is usually attached only lightly, and offers no increased difficulties in the removal of the entire capsule. The malignant tumors infiltrate into the surrounding tissues and are inoperable. Occasionally the capsule of a benign tumor is so firmly adherent and in such a relatively inaccessible position, closely associated with the large arterial and venous trunks, that its separation is attended with added risk. In such cases, after the removal of the cervical portion of the goiter, the contents of the intrathoracic capsule may be enucleated entirely by dissecting with the finger without much loss of blood. The edges of the capsule are steadied by forceps, the finger of the left hand is placed laterally and posterior to the capsule to control the inferior thyroid artery by compression. With the index finger of the right hand the capsule is ruptured and its adenomatous content is shelled out. The sac is then packed with gauze, which is removed in four or five days.

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6. Lilienthal, H.: A Case of Mediastinal Thyroid Removed by Transsternal Mediastinotomy, Surg., Gynec. & Obst. **20**:589-593, 1915.

COMPLICATIONS

Tracheal obstruction may be encountered either during the operation or several hours later. The collapse of the trachea during the course of the operation is frequently due to pressure obstruction from the goiter or from the forceps; it occurs most frequently during the elevation of a large growth on one side, or immediately after, and is usually the result of an adenoma, possibly unsuspected, lying behind the trachea or below the sternum on the opposite side. The obstruction is relieved by the elevation of the second growth. A tracheotomy may have been necessary before the elevation of the second growth; usually the opening in the trachea can be closed at the completion of the operation. In this series it was not necessary to do a tracheotomy during the course of the operation. Marked tracheal deformities, such as the scabbard trachea, due to bilateral pressure resulting in softening of the cartilaginous rings of the trachea, are not infrequently seen, and are often associated with obstructive breathing, at times requiring the opening of the trachea. However, the indication for tracheotomy in these cases does not usually appear for from twenty-four to forty-eight hours after the operation. A tracheotomy may also be necessary for the dyspnea associated with cord paralysis incident to the operation. The dyspnea of patients with profound hyperthyroidism may be confused with the obstructive dyspnea; but I wish to emphasize the importance of opening the trachea in all cases if any doubt exists, for thus a life will occasionally be saved. In performing a tracheotomy in a thyroidectomized patient, the mediastinal space should always be well walled off by a pack before the trachea is opened to prevent a possible fatal mediastinitis. Eight postoperative tracheotomies were performed in this series, five for obstructive dyspnea and three for toxic dyspnea. All patients in the former group survived and all in the latter died. Obstructive breathing necessitated a tracheotomy in twenty-four hours after operation in three patients, in thirty-two hours in one, and in forty-eight hours in one.

Hemorrhage.—Postoperative hemorrhage is not an infrequent complication following a thyroidectomy. It occurs usually within the first six hours, and is easily diagnosed by the increasing obstructive breathing, choking spells, cyanosis, and a tense swelling in the neck. The wound should be reopened immediately, the clot evacuated, and the open vessel clamped and tied. There were three cases of secondary bleeding in this series. The frequency of secondary hemorrhage is due, first, to the fact that the remaining portion of the thyroid gland is movable, and, following the movements of the trachea, a ligature may become loosened; and, second, that veins are often broken during

the dislocation of a lobe from its bed without the knowledge of the operator. Traction may temporarily occlude the opening in the vein and a clot may form, which will be forced out a few hours later by the patient's straining. To prevent secondary bleeding demands more than the exercise of care in primary hemostasis. The patient should be induced to strain or cough while on the operating table, when the "secondary hemorrhage" can be controlled.

Paralysis of the Vocal Cords.—Preoperative and postoperative examination of the larynx should be a routine in all cases. Injury to the recurrent laryngeal nerve may be either direct or indirect. The direct causes may be stretching or severing the nerve, or crushing or compressing by forceps or suture (Fig. 14). The indirect causes may

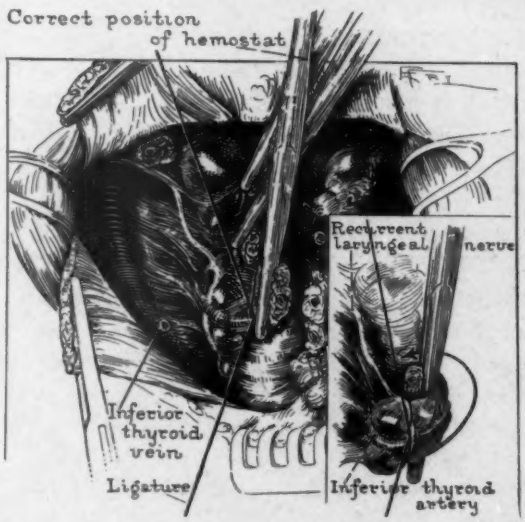

Fig. 14.—Manner in which the recurrent laryngeal nerve may be caught in the ligature by twisting the forceps.

be the traction incident to the swelling in the neighboring tissues, or to edema of the nerve itself, or the nerve may be compressed in scar tissue. In this series a postoperative examination of the larynx was not recorded in ninety-two patients. A positive finding from two to four weeks after the operation, varying from edema, lagging, slight abductor or adductor paresis to a recurrent paralysis, was reported in 170 patients. The right cord was afflicted in sixty-seven, the left in seventy, and both in thirty-three. There was aphonia in two of these, in one of whom the gland had been extirpated for cancer. In the greater number of these patients no change in the voice could be noted, or only a slight huskiness similar to that of many of the patients with negative laryngeal findings. A direct injury to the nerve during the

course of the operation may often be detected immediately by the sudden change in breathing, such as rasping, with inspiratory stridor. Cutting the offending suture may be followed shortly by the return to normal.

Tetany.—Removal of the parathyroids or damage to their blood supply, evidenced by the development of a permanent tetany, is extremely rare following thyroidectomy. Even in cancer of the thyroid, when an attempt is made to remove the entire gland, serious injury to the parathyroids is uncommon. In this series, postoperative tetany occurred in six patients. In all it was temporary; in five it was evidenced by slight cramping of the fingers and toes, and occurred from twelve to forty hours after operation, lasting from twenty-four to forty-eight hours. One patient had convulsive seizures.

Air Embolus.—The danger of extensive air embolism in operations near the root of the neck often is not appreciated. In the removal of large substernal goiters associated with numerous dilated veins the recognition of this complication is of especial importance. The thyroid veins run directly into the larger venous channels, the internal jugular and the innominate. If thyroid veins are torn accidentally and the opening is not recognized, an opportunity is afforded for the aspiration of a large quantity of air into the vein. The accident may occur during the course of the operation or shortly afterward, during straining or coughing. Cyanosis and dyspnea develop, rapidly becoming more intense. The pulse is little affected until the last. Necropsy reveals the right side of the heart filled with frothy blood. There was no incidence of air embolism in this series.

RESULTS

The results of the operation for the removal of substernal and intrathoracic goiters are very satisfactory. The patients are almost immediately relieved of most distressing symptoms, and they are most grateful. The mortality is low. There were sixteen deaths in this series of 542 operations (2.9 per cent.). Two may be classified as due to faulty technic, one of these to the loss of blood after a thoracotomy for the exploration of a huge intrathoracic cancer, and the other to septicemia, probably originating from the wound. Three patients died from pneumonia. Eleven (68 per cent.) died from acute hyperthyroidism seventy-two hours following operation. The average preoperative basal metabolic rate was + 43. These patients were recognized as bad surgical risks; most of them had been treated medically before the operation.

ARE THERE RELIABLE CRITERIA OF OPERABILITY IN EXOPHTHALMIC GOITER?*

DAVID CHEEVER, M.D.
Assistant Professor of Surgery, Medical School of Harvard University
BOSTON

For the purpose of this inquiry, it may be admitted that exophthalmic goiter and the related condition, toxic adenoma, are characterized by an altered function of the thyroid gland, chiefly an increased secretion; and that the reduction of this activity, by operative removal of a part of the gland, is followed in the great majority of cases by a prompt and more or less lasting amelioration of symptoms. It may also be admitted that in spite of the fact that many patients, especially those with exophthalmic goiter, will recover or be improved by medical measures and many more by appropriate irradiation by roentgen ray or by radium, nevertheless, in certain refractory cases operation is much the best and perhaps the only solution of the problem.

The three chief disadvantages of operative treatment are: first, the associated mortality; second, the ordeal of the operative experience, and third, the scar. The two latter may be dismissed because in expert hands they are trivial and wholly out of proportion to the advantages to be gained. The operative mortality remains, then, the one great drawback, and it is especially serious because it is more difficult to weigh the evidence and predict the outcome in this class of cases than in almost any other. No other peripheral operation not involving the great body cavities carries with it the uncertainties associated with interference with the thyroid gland in cases of hyperthyroidism. Criteria of operability are therefore much to be desired.

It is disappointing in searching the recent literature on the operative treatment of dysthyroidism, to find so few definite statements on the subject of operability. This is doubtless because the various factors concerned in the toxemia are not susceptible of accurate measurement. Almost every writer makes general statements to the effect that an operation must not be performed in the acute stage, or during a crisis, or if the toxemia is very marked, or in the presence of serious organic visceral changes, especially in the heart, liver and kidneys. Others refer in general terms to the excess over normal of the basal metabolism, to the epinephrin test, and to the way in which the shock

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of various preliminary minor procedures is borne. Thus Crile [1] says that caution must be observed and the operation terminated when the pulse reaches the "danger point," but does not state what that point is. Mason [2] says: "In extremely toxic cases it is impossible to determine how much operative interference will be tolerated; the history, general condition, pulse and pulse pressure and metabolic rate give an index to the degree of intoxication," but he does not say what degree of variation from the normal contraindicates operation. Sistrunk [3] declares that "in general a high metabolism plus symptoms of marked toxicity contraindicates surgical procedures," and adds that it is a perplexing problem to decide how toxic a patient is and how much damage has been produced by the disease. He is more specific in saying that "primary partial thyroidectomy is not advised in cases with a metabolism of + 60 to + 70 per cent." and refers to the practice at the Mayo Clinic of performing one or more ligations, possibly preceded in bad cases by injections of boiling water or quinin and urea hydrochlorid, "both to prepare the patient for thyroidectomy and as a means of testing patients about whose fitness for operation there is a doubt." Lahey [4] says that "decision as to the toxicity in a given case is not based on exact percentages of tachycardia, increase in nervousness, loss of weight, etc." Barnhill [5] tries to give an exact criterion, stating that "metabolism of + 33 and a pulse rate of over 120 contraindicate primary thyroidectomy." McCaskey [6] says: "Operative risk increases to an appalling extent when the metabolic rate attains an increase of around 100 per cent." Judd [7] makes a helpful suggestion, in stating that loss of body weight and loss of strength indicated by weakness of the extensor muscles, constitute important evidence of the degree of toxicity, and says further that the surgical mortality is unduly high when the toxemia is progressive, or at the peak of a hyperthyroid wave. De Courcy [8]

1. Crile, G. W.: The Surgical Treatment of Exophthalmic Goiter, Surg., Gynec. & Obst. **30**:27 (Jan.) 1920.

2. Mason, J. T.: Mistakes in One Hundred Thyroidectomies, J. A. M. A. **75**:161 (July 17) 1920.

3. Sistrunk, W. E.: The Selection of Operations for Exophthalmic Goiter, J. A. M. A. **75**:306 (Jan. 31) 1920.

4. Lahey, F. H.: Preliminary Ligation in Hyperthyroidism, Boston M. & S. J. **181**:618 (Nov.) 1919.

5. Barnhill, J. F.: Surgery of the Thyroid, J. A. M. A. **74**:1558 (June 5) 1920.

6. McCaskey, G. W.: Basal Metabolism Determinations in General Internal Diagnosis, J. A. M. A. **74**:927 (April 3) 1920.

7. Judd, E. S.: Results of Operations for Adenoma with Hyperthyroidism and Exophthalmic Goiter, Ann. Surg. **72**:145 (Aug.) 1920.

8. DeCourcy, J. L.: Local Anesthesia in Operations upon the Thyroid Gland, Am. J. Surg. **33**:245 (Oct.) 1919.

says that "thyroidectomy is not advisable if the pulse after moderate exertion exceeds 120." Means and Aub,[9] discussing especially the significance of basal metabolism, show from cases under their observation that as regards the parallelism between the pulse rate and metabolism, cases may be separated into two groups: (1) those in which the pulse rate (when plotted in a uniform way with a base line of a pulse rate of 50 and a normal metabolism, and a top line of a pulse rate of 150 and metabolism + 100 per cent.) runs ten or more points above the metabolism curve, and (2) those in which the pulse curve coincides with, or runs below, the metabolism curve. They remark that of the five operative fatalities reported by them, four belonged to Type 2 and only one to Type 1. They further say that a rising metabolism in spite of complete rest is an apparent contraindication to operation.

In a subsequent paper, Means[10] emphasizes the special importance of the comparison of the metabolism curve, pulse curve, and the gain or loss of body weight in the estimation of the patient's degree of toxemia, and presents charts showing these variables, and states that the prognosis in the sympathetico-tonic type (Type 1, of his previous paper) is better than in the vagotonic type (Type 2). In the former it seems to matter very little whether medical or surgical means are employed, while in the latter recovery may take place with the roentgen ray alone; and although surgery may be necessary, the risk is much greater than in the other type. There is some evidence to show that this risk may be reduced by exposing the thymus to roentgen ray before surgery is undertaken.

It is thus seen that, with notable exceptions, recent writers have found it impossible to formulate any approximately exact criteria of the ability of the patient to withstand operation, and very few have furnished the important data concerning their fatal cases which might afford statistical evidence from which, in time, reliable standards might be deduced.

Various suggestions for determining the resistance of the patient to operative trauma may be enumerated under these headings:

(1) The history, with special reference to the age of the patient, the degree of asthenia, the loss or gain in weight, and the presence or absence of a "wave" of hyperthyroidism.

(2) The general clinical picture, including as an important factor, the mental attitude.

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9. Means, J. H., and Aub, J. C.: The Basal Metabolism in Exophthalmic Goiter, Arch. Int. Med. **24**:645 (Dec.) 1919.

10. Means, J. H.: Hyperthyroidism—Toxic Goiter, Med. Clin. North America, **3**:1077 (Jan.) 1920.

(3) The presence or absence of organic disease of the heart and other viscera, especially the kidneys, liver, and the cerebrum.

(4) The presence or absence of an enlarged thymus.

(5) The blood pressure.

(6) The pulse rate.

(7) The epinephrin test.

(8) The administration of thyroid extract.

(9) The determination of the basal metabolism.

(10) The manner in which the patient withstands the strain of preliminary procedures involving psychic disturbances or surgical trauma.

Some of these suggestions may be dismissed with but a word or two of comment, as probably lacking in significance, or not susceptible of accurate determination. Thus, the general clinical picture is doubtless of importance in direct proportion to the experience and shrewdness of the surgeon, who often may gain a reliable impression of toxicity from signs or symptoms whose degree cannot be expressed in definite terms, such as "nervousness," "emotionality," "apprehension," and "exhaustion." The psychic factor is no less difficult to gage; but it is not too much to say that operation should not be undertaken unless the patient is hopeful and confident of recovery. The presence of organic disease of the viscera is of disputed significance. Gordinier [11] says that "all cases showing myocardial insufficiency or serious arrhythmias should be treated medically." Most authors refer to a "toxic myocarditis," and degeneration of the liver and kidneys; but it is difficult to find references in the literature to the actual organic change in the two latter viscera. A long continued thyrotoxicosis leads in time to a chronic degeneration of the heart muscle, with dilatation, serious arrhythmias, decompensation, and secondary renal and hepatic changes from passive congestion; but in the earlier years of the disease (except in very acute fulminating cases), there is no decompensation, usually no arrhythmia, the blood pressure is high and there is no obvious interference with the function of the liver and kidneys. In patients that have died of exophthalmic goiter there are no characteristic lesions to be found in the heart, liver or kidneys.[12] In the cases about to be reported, none showed organic changes in these organs except more or less enlargement of the heart, probably with dilatation, never, however, with decompensation.

The interrelation between the various endocrine glands is but ill understood, and this holds true of the thyroid and thymus. Melchior [13]

11. Gordinier, H. C.: The Medical Treatment of Graves' Disease, New York State J. M. **18**:267, 1918.

12. Wolbach, S. B.: Personal communication.

13. Melchior, E.: Ist der post-operative Basedowtod ein Thymustod? Berl. klin. Wchnschr. **54**:837, 1917.

says that from 75 to 85 per cent. of cases of exophthalmic goiter show enlarged thymus glands, that cases in which it is not enlarged are very severe, and give a much worse prognosis. Nordmann,[14] on the contrary, records that in eleven fatal cases of thyroidectomy a persistent and enlarged thymus was found. Most authorities take this view, and advise irradiation of the thymus, whether it is demonstrably enlarged or not, to diminish its activity before attacking the thyroid. For the present, it must be accepted that enlargement of the thymus is a serious contraindication to operation.

The pulse rate is justly recognized as a valuable index of thyrotoxicosis; but whether it can be called a reliable guide is doubtful. Judd [7] well says that the pulse rate (and also the nervousness and tremor) are influenced by so many other factors that their value is limited. Its significance will be further discussed in connection with metabolism. The blood pressure is nearly always elevated, and except when there is severe cardiac decompensation, or when the fall in pressure accompanies other signs of a fatal termination, the degree of its variation from the normal is not of much help in prognosis.

Among tests depending on increasing the amount of ductless gland hormone in the circulation and observing the reaction, may be mentioned the administration of thyroid extract, and of epinephrin. Harrower [15] advises the use of desiccated thyroid for three days, stating that from the severity of the reaction may be inferred the presence of hyperthyroidism and its approximate degree. Goetsch [16] arguing from the researches of Cannon and others that in states of hyperthyroidism there is a sensitization of the sympathetic system, and therefore a hypersensitiveness to epinephrin, has suggested the injection of the latter, and the recording of the succeeding variations in pulse and respiration rate, blood pressure, vasomotor and psychic phenomena, which constitute a reaction whose severity is proportional to the degree of hyperthyroidism. This test has proved a valuable means of differentiating between certain obscure cases of exophthalmic goiter, or of thyroid adenoma with thyrotoxicosis, and other conditions unrelated to the thyroid gland (neurasthenia, incipient tuberculosis). Further expe-

14. Nordmann: Thymusextirpation bei Basedowsche Krankheit, Deutsch. med. Wchnschr. **46**:109 (Jan. 22) 1920.

15. Harrower, H. R.: A Simple Therapeutic Test of Thyroid Function, Med. Rec. **94**:196 (Aug. 3) 1918.

16. Goetsch, E.: Newer Methods in the Diagnosis of Thyroid Disorders, Pathological and Clinical, New York State J. M. **18**:259, 1918.

17. Peabody, F. W.; Sturgis, C. C.; Tompkins, E. M., and Wearn, J. T.: Epinephrin Hypersensitiveness and Its Relation to Hyperthyroidism, Am. J. M. Sc., to be published, and Footnote 7.

rience seems to show, however, that the test is sometimes at variance with both the clinical picture and the basal metabolic rate, and occurs in conditions other than hyperthyroidism. It cannot, therefore, be accepted as one of the criteria for which search is being made.

The introduction of practical clinical methods for the determination of the basal metabolism has justified the hope that a method is at hand for determining accurately the severity of a case of hyperthyroidism. It may be accepted as proved that the thyroid gland presides over the rate of metabolic processes in the cells of the organism; that in overactivity of the gland, the metabolic rate is correspondingly increased, and that in the resting, postabsorptive, afebrile state, no cause outside the thyroid gland acts to raise the metabolism in marked degree, except pituitary disorder, leukemia, and one or two other unexplained conditions.

Sandiford [18] says: "The basal metabolic rate is of great value in thyroid disorders because it gives a very accurate mathematical index of the functional activity of the thyroid gland." Du Bois [19] says: "The heat production is an index of the severity of the disease and of the effect of treatment." McCaskey [6] states that the metabolism is an accurate index of goiter toxicity. Judd [7] declares that "the degree of hyperthyroidism estimated from the clinical features and that determined by basal metabolism practically always correspond." Noble [20] states that "by determining the basal metabolic rate the patient can be placed on a definite scale of toxicity." If the last statement is true, experience should enable us to determine (within limits of error) a level of basal metabolism below which operation will be safe and above which it will be fatal. Unfortunately, while the metabolic rate establishes the activity of the thyroid gland, it may not necessarily define the toxemia (if indeed there exists a true toxemia in addition to the exaggerated function of the gland), and it certainly does not necessarily indicate the patient's resistance to noxious influences, whether toxic or hyperfunctional.

From this brief summary, it is evident that the most promising criteria of a thyrotoxic patient's condition may be gained from certain points in the history, the variation in body weight, and the elevation of pulse and metabolism. With reference to these points, the four fatal

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18. Sandiford, I.: The Basal Metabolic Rate in Exophthalmic Goiter (1,917 Cases), with a Brief Description of the Technic Used at the Mayo Clinic, Endocrinology **4**:71 (Jan.-Mar.) 1920.

19. DuBois, E. F.: Basal Metabolism in Exophthalmic Goiter, Arch. Int. Med. **17**:915 (June) 1916.

20. Noble, T. B.: Lobectomy vs. Ligation of the Vessels in Toxic Goiter, J. Indiana M. A. **12**:230, 1919.

DRS. RICHARDS, IRVINE, RIDGES, SNOW & TYREE

operative cases which have occurred at the Peter Bent Brigham Hospital have been analyzed, and to them are added six other cases which seemed to illustrate the matter, because of a very high metabolic rate, or because a fatal issue from operation was narrowly averted.

REPORT OF CASES

CASE 1.—M. G., No. S-10209, a Jewess, aged 22 years, had had an enlarged thyroid for five years the etiology of which was obscure. There had been increasing symptoms for the last two years, with marked exacerbation during the last six months and a loss of weight of 17 pounds. Examination revealed the typical syndrome of exophthalmic goiter with no serious visceral lesion: the general impression created was that she was "not extremely toxic." On March 28, 1919, her pulse was 125, metabolism + 70, and weight 50 kilograms. Because of the high metabolism, a preliminary ligation of both superior thyroid arteries was performed under procain. The patient became nervous and difficult to control on the operating table; but the pulse did not exceed 130. There was persistent postoperative vomiting, and the following day the temperature was normal, but the pulse had risen to 190. On the second day, the temperature began to rise, and the pulse became more rapid; on the third day the temperature reached 103 F., and the patient lapsed into coma. A metabolism determination was made and showed + 62, with a pulse of 200. The patient died on the fourth day (Chart 1).

Comment.—The pulse and metabolism before operation in this case show, so far as one determination goes, that it belongs to Type 2 ("vagotonic") of Means and Aub, which was thought to offer a worse operative prognosis than Type 1 ("sympathetico-tonic"). The wide discrepancy between pulse and metabolism in the moribund state is probably not significant. The general impression of the patient's resistance was erroneous. The undertaking of a minor preliminary procedure was correct; but it might have been made even less of a tax by confining the ligation to one vessel, and perhaps the patient's behavior on the operating table might have suggested this modification. During the postoperative course, measures might have been taken to reduce the temperature had its significance been realized (Crile); but it is interesting to note that although every degree of fever increases the metabolism by + 10, in this case the reading taken in coma, with a temperature of 103 F., showed a lower metabolism than before operation with a normal temperature. Presumably the moribund condition explains this, and also the wide discrepancy between pulse and metabolism, at the second determination, where they certainly are of Type 1 ("sympathetico-tonic").

CASE 2.—R. K., No. S-7532, a Jewess, aged 22, had had an enlarged thyroid for five years, the etiology of which apparently was a fright. At the onset, there was an acute wave of hyperthyroidism, with 53 pounds loss of weight in five months. She refused operation at another hospital, and by the end of a

year the wave had subsided. She considered herself "well" and remained so until one year before, when the present acute exacerbation occurred. During March, 1917, she was treated by roentgen ray at the Massachusetts General Hospital.

She was admitted to Peter Bent Brigham Hospital, July 16, 1917. Examination revealed a typical picture of exophthalmic goiter, with a pulse of 120,

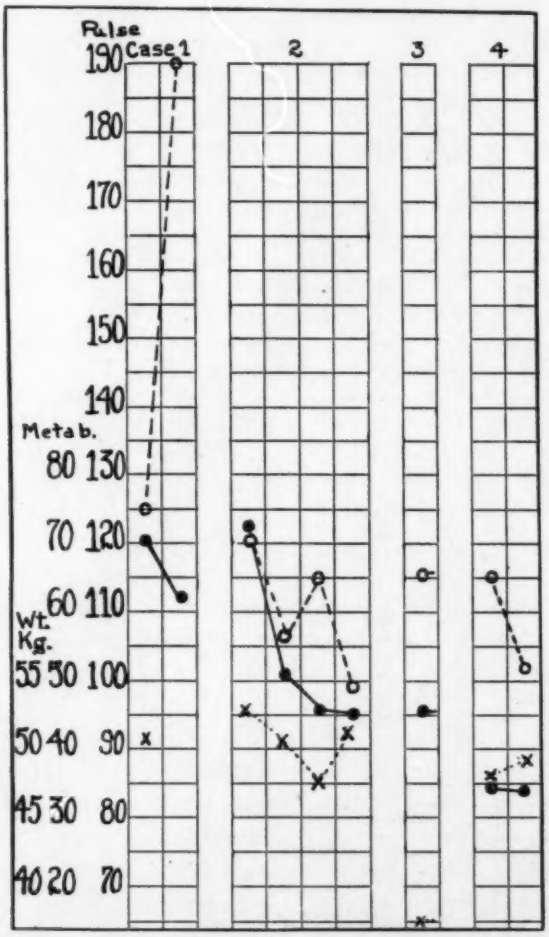

Chart 1.—Pulse, metabolism and weight variations in Cases 1, 2, 3 and 4. In this and the following charts, the solid line represents metabolism; the broken line, pulse, and the dotted line, weight.

and metabolism of +72. No serious visceral lesion was noted. On account of the high metabolism, a ligation of the left superior thyroid artery was performed under procain, without excessive reaction. Five days later, on July 24, the pulse was 108 and the metabolism had fallen to +50, and she had lost about 3 kilograms in weight. On July 27, the right superior thyroid vessel was tied. Five days later, the pulse had risen to 115, and the weight

had dropped nearly 3 kilograms more. She was discharged to allow her to gain the full benefit of these procedures, and two months later, on Oct. 19, 1917, under ether anesthesia, the right lobe and a portion of the left were removed. The operation was badly borne, and was followed by an excessive reaction with rapid rise in temperature and death in six hours (Chart 1).

Comment.—At first, this patient's chart suggests that the case belongs to the Type 2 "vagotonic" group, but immediately after the ligation it partook more of the "sympathetico-tonic" type, only to return again at the final determination. It is probable that this variation makes it impossible to assign it definitely to either group. Every precaution to insure safety of operation was taken, and every standard of operability seems to have been met, and it is difficult to understand how a fatality could have been predicted in this case.

Case 3.—M. H., No. S-4971, female, colored, aged 32 years, had an enlarged thyroid of two and one-half years' duration; the etiology was obscure. The patient had had the usual symptoms of exophthalmic goiter, with especially severe dyspnea and weakness, so that she could hardly walk. She had probably lost about 15 pounds, in spite of resting quietly at home for four months previous to admission, on July 27, 1916. Examination disclosed a typical picture of the disease with no visceral lesion except the usual cardiac enlargement and systolic murmur, but no decompensation. On June 24, the pulse was 114, and the metabolism + 46. The opinion of the medical service was that the case was especially suited for surgery, and the consulting surgeon made the same comment. Operation was performed on July 3, 1916, under ether anesthesia, the whole of the enlarged right lobe and one half of the left being removed without accident. The pulse was 130 at the start, but in a few minutes rose to 200, and thereafter varied between 180 and 200. She was put to bed in good condition, and the pulse was 130 six hours later. About eighteen hours after operation, the pulse began to rise, accompanied by the temperature, reaching 280 and 107 F., respectively, before her death about twenty-six hours after operation (Chart 1).

Comment.—So far as one determination can be depended on, this patient belonged to Type 1 "sympathetico-tonic" group. The moderate elevation of the metabolism and her apparent nervous control led to a false sense of security. In advanced "thyrotoxicosis," the lack of nervous control is sometimes shown by an apathetic state. The marked muscular weakness (Judd [7]) might have suggested a grave prognosis. The actual loss of weight was unknown, and it would have been wise to have kept the patient longer under observation, when further loss of, or failure to gain, weight under absolute rest might have led to more caution. A minor operative procedure might have been undertaken to determine her resistance. Gas-oxygen would have been preferable to ether anesthesia. Perhaps the rapid rise of the pulse to 200 during the operation should have led to more conservatism (although this has occurred in many successful cases). The postoperative pyrexia should have been controlled. Its significance was not realized.

CASE 4.—F. D., No. S-12827, a Jewess, aged 31 years, had had an enlarged thyroid for fourteen years; the etiology was obscure. At first there was a period of marked toxicity, treated by rest for three years, when she was told she was "cured." Three years ago the exophthalmos again became marked without aggravation of symptoms; two months ago toxic symptoms again became evident. Examination revealed the clinical picture of exophthalmic goiter of a rather mild type, and no visceral lesions. On July 22, 1920, the metabolism was + 35, the pulse 115, and the weight 47.7 kilograms. Five days later the metabolism was + 35, the pulse 101, and the weight had increased slightly. The impression gained was that the "toxic symptoms are not marked at present." At operation, July 28, 1920, under gas-oxygen and procain anesthesia, the larger left lobe and isthmus, or about two thirds of the gland, were removed. It was not very vascular: the pulse ranged from 100 to 120, and finally rose to 140 at the close of the operation. Later, the pulse and temperature rose progressively to 200 and 106 F., respectively, and death occurred in thirty hours (Chart 1).

Comment.—As far as shown by two determinations, the pulse ranged relatively considerably higher than the metabolism and the case belongs in the Type 1 "sympathetico-tonic" group. There seems to be little to criticize in the conduct of this case, except that perhaps every patient should be under observation longer (which may not be possible in hospital patients). Perhaps every patient should be subjected to a minor operative procedure, no matter how unnecessary such a precaution appears.

CASE 5.—J. E. M., No. S-12207, male, American, aged 26 years, was admitted Sept. 12, 1919, to the Medical Service. The etiology of his condition was obscure, the duration was one and one-half years, and the general impression gained was that he was "very toxic." The symptoms and examination were typically those of exophthalmic goiter, without evident associated visceral disease. The Wassermann reaction was positive. On admission, the metabolism was + 65 and the pulse 97. One month later under complete rest and overfeeding, his metabolism had jumped to 99, and his pulse to 122, and he had lost nearly 3 kilograms. One month later, during which time he had two irradiations over the thymus region, his metabolism had increased to + 116 and his pulse to 134, and he had lost nearly 2 kilograms more. Two months later, during which interval he had eight irradiations over the thyroid and one over the thymus, with continued rest in bed, his metabolism had dropped to + 68 and his pulse to 116, and he had nearly gained back the weight lost since admission. During the next month, he had two more roentgen-ray treatments, and had a heart block, during which the metabolism had fallen to + 48 and the pulse to 85. During his seven months' stay in the hospital, the subjective improvement was but slight and he had lost 3½ kilograms in weight.

April 10, 1920, the right superior thyroid artery was tied under procain; the pulse was 160 and the reaction fairly severe.

On April 20, the left superior thyroid was ligated. On account of the very loud bruit and thrill over the right inferior artery, this vessel was ligated on May 3, 1920. One week later, as a result of these preliminary procedures, the metabolism was essentially the same, + 46, and the pulse had gone to 118,

the heart block having terminated, and he had gained 2 kilograms in spite of the operative ordeals. He was subjectively improved, his morale as regards operation was thoroughly established, and he was full of confidence. A week later, his metabolism had risen 10 points, but his weight was gaining. On May 27, under gas-oxygen, the entire right lobe, the isthmus, and one half of the smaller left lobe were removed. The pulse was 170 at the beginning of the operation and reached 210 at the end, when it became irregular, of poor quality, and the respiration jerky and finally Cheyne-Stokes in type. The condition was very precarious for twenty-four hours, although the temperature

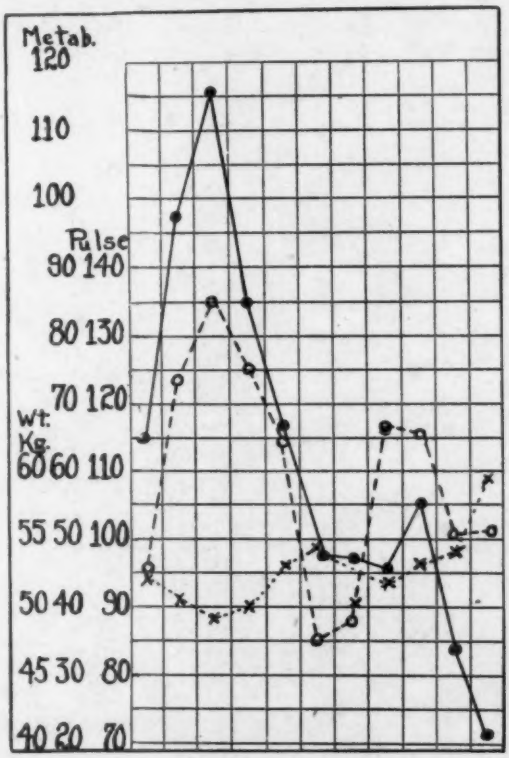

Chart 2.—Pulse, metabolism and weight variations in Case 5.

never went over 101 F. Rapid improvement then began, and two weeks later the metabolism was + 33, the pulse 100, and he had gained 1½ kilograms. At this time he was discharged from the hospital. Two months later his metabolism was + 21, pulse 100, and he had gained 5½ kilograms more. Since then he has led a nearly normal life (Chart 2).

Comment.—At first the relation between this patient's pulse and metabolism during treatment suggested that he belonged to the Type 2 "vagotonic" group. Finally he tended more to the Type 1 "sympathetico-tonic" group. The building up of his morale and gaging his resistance by minor procedures were perhaps of great importance.

CASE 6.—F. K., No. S-8185, an American, male, aged 28 years, had had an enlarged thyroid for two years, and the etiology was obscure. There had been 45 pounds loss of weight and the typical history, symptoms, and signs of exophthalmic goiter. The metabolism was +116 and the weight 60 kilograms on March 7, 1917. After ten months of rest at home and in the Adirondacks, his metabolism was +26, his pulse 76, and his weight had increased 7½ kilograms. He showed considerable muscular weakness, however, and was unable to work. Feb. 11, 1918, under procain anesthesia, the right lobe and isthmus were removed. It was intended to remove a large portion of the left, but the difficulty of hemostasis was so great that the

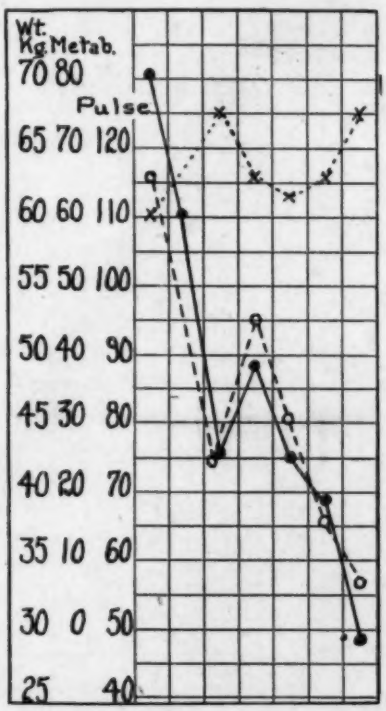

Chart 3.—Pulse, metabolism and weight variations in Case 6.

operation was terminated. (He proved to have a distinctly hemophilic history.) The operation seemed to be well borne; but the first six days of convalescence were marked by grave toxemia and high fever, and he was considered in a precarious condition. Ten days later, both metabolism and pulse had increased slightly. He was discharged nineteen days after operation, and since then his metabolism has dropped to —1, and his pulse to 58, and he appears and feels normal in every way (Chart 3).

Comment.—This patient's pulse and metabolism chart showed that he should be classed with the Type 2 "vagotonic" group. Perhaps this explains the serious postoperative course in spite of a moderate elevation of metabolism, but it seems possible that it was due to the failure

to remove enough of the gland. If general anesthesia had been used, this could probably have been done. The final result is excellent.

CASE 7.—M. M., No. S-6812, American, female, aged 43 years, had had thyroid enlargement for two years; and there were the typical history, symptoms and signs of exophthalmic goiter, without serious associated visceral lesion. She was admitted to the hospital, May 31, 1917. The metabolism on June 5 was + 73, the pulse 90, and the weight 51.2 kilograms. On June 12, under procain anesthesia, both superior thyroid vessels were ligated with little immediate reaction. There was an immediate slight rise, then a gradual decline in both pulse and metabolism, and an associated gain in weight, until, on Feb. 9, 1920, the metabolism was — 12, the pulse 57, and she had gained 14 kilograms and was leading a normal life (Chart 4).

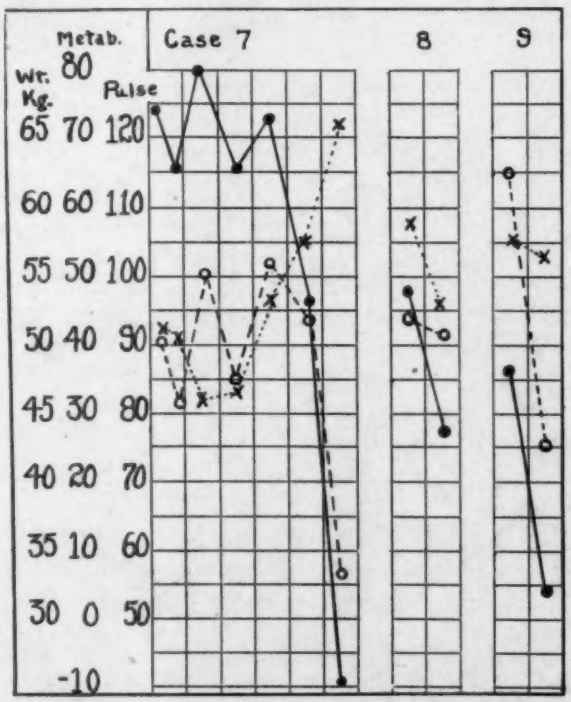

Chart 4.—Pulse, metabolism and weight variations in Cases 7, 8 and 9.

Comment.—The chart shows the patient to be a typical example of the Type 2 "vagotonic" group, in spite of which and of a high metabolism, she showed only mild toxicity and little operative or postoperative reaction. The case is interesting as being a cure from simple double superior ligation.

CASE 8.—G. G. H., No. S-12530, Canadian, female, aged 34 years, had had an enlarged thyroid for two years; the etiology was not clear, and the history, symptoms, and examination were quite typical. On admission, her metabolism was + 49, the pulse 94, and she gave an impression of only moderate toxicity.

She appeared controlled and desired operation. The pulse which was usually about 100, went to 160 during the examination. On June 2, 1920, under gas-oxygen, the enlarged right lobe and one half of the left were removed. The pulse started at 160, went to 210, and the patient was drenched with sweat. The postoperative course was very stormy, with wild delirium, constant vomiting, a temperature of 104 F., and the cardiac impulse shaking the whole bed. She finally recovered, and the metabolism, ten days after operation, was + 28, the pulse 92, and she was discharged much improved. (Chart 4).

Comment.—Her chart, judging by two observations, shows that she belongs in the Type 2 "vagotonic" group. A minor procedure should have been undertaken to establish her resistance to operation.

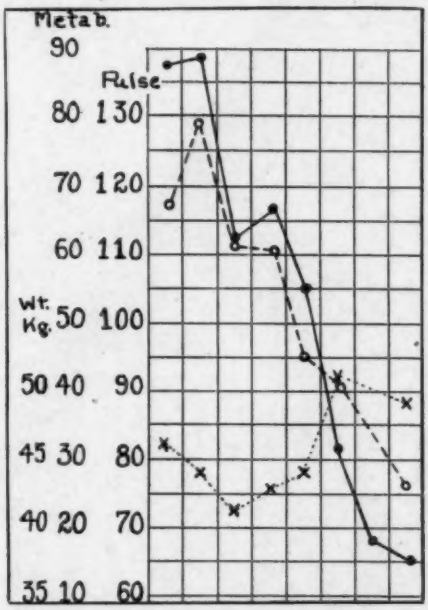

Chart 5.—Pulse, metabolism and weight variations in Case 10.

CASE 9.—C. L., No. S-12629, American, female, aged 23 years, had had an enlarged thyroid for six months: the etiology was apparently an emotional strain. The symptoms included a marked tendency to diarrhea, but were otherwise of moderate severity. The examination gave the impression of very moderate toxicity. The metabolism after a week in bed was + 39, and the pulse 114. On June 21, 1920, under gas-oxygen, the major portion of both lobes was removed. The pulse went to 215, while the respirations reached 60, and were alarmingly shallow. The condition seemed very precarious for twenty-four hours, but the later postoperative course was good. Ten days later the metabolism was + 3 and the pulse 75. Final recovery was complete (Chart 4).

Comment.—This patient's chart shows that she must be placed in the Type 1 "sympathetico-tonic" group. Nevertheless, the operation itself was poorly withstood, and there was apparently nearly a fatal issue.

CASE 10.—M. E. D., No. S-4536, American, female, aged 21 years, had had thyroid enlargement for six months; the etiology was doubtful. Her history, symptoms, and physical examination were typical of exophthalmic goiter. The metabolism on March 24, 1916, was +88, and the pulse 118. On April 10, 1916, under ether anesthesia, the enlarged right lobe and isthmus, constituting about two thirds of the gland, were removed, and the left superior thyroid artery ligated. Although the pulse reached 210 and the respirations 50 during the operation, the condition did not seem alarming, and the postoperative course was not very severe. A series of determinations since have shown steadily declining pulse and metabolism, until on Oct. 2, 1920, the metabolism was +15 and the pulse 77, in spite of the fact that she had passed through pregnancy and confinement successfully and was constantly subjected to an unusual and severe psychic strain (Chart 5).

Comment.—This patient's chart shows essential correspondence in the metabolism and pulse curves, and she therefore belongs in the Type 2 "vagotonic" group, in spite of which and of a very high metabolism, she withstood a primary thyroidectomy under ether anesthesia without alarming reaction. Nevertheless, it would have been wise to establish her "preoperative morale" by a minor procedure.

CONCLUSIONS

Can satisfactory deductions be drawn from these cases to assist in determining reliable criteria of operability? The suggestion of Means and Aub that patients falling into their Type 2 "vagotonic" group give a more serious prognosis, does not seem to be wholly sustained by the cases above presented. Of the four fatal cases, two belonged to the "sympathetico-tonic" and one to the "vagotonic" group, while one showed different phases, permitting its classification in either group. Of the others, Cases 5, 6, 8 and 9 showed very serious postoperative reactions, and of these, three can be classified as "vagotonic" and one as "sympathetico-tonic." The remaining patients, Cases 7 and 10, were "vagotonic" in type with high metabolism, but both made good recoveries without undue reaction; the operation being ligation in one and the radical procedure in the other. Evidently an investigator with a theory to defend could find in these cases support for either point of view. Perhaps the weight of evidence favors the impression that the "vagotonic" group gives the more serious prognosis.

As far as these cases go, no definite level of pulse or metabolism can be said to constitute an absolute contraindication. One death occurred in a patient with a metabolism as low as +33. It is certainly striking that three of the four fatal cases were those of Jewish women, since in a series of cases of exophthalmic goiter at Peter Bent Brigham Hospital, the proportion of Jewish women was less than one-fifth. It seems worth while to allude more specifically to the possibly very great importance of testing a patient's ability to withstand operative trauma

by one or more preliminary minor procedures. (No comment is intended to be made in this paper on the therapeutic effect of these measures, although they are usually, of course, designed to lessen the thyrotoxicosis.) Such a point of view is mentioned by many writers. Watson [21] says that preliminary injections of saline solution or sterile water should be made into the gland "to raise the patient's threshold of stimuli, thereby preventing an acute attack of hyperthyroidism which might otherwise follow the first quinin and urea injection." Sistrunk [3] speaks of ligation as a means of testing the ability of the patient to stand any operative procedure without precipitating a severe crisis of hyperthyroidism.

It seems reasonable to offer the subjoined tentative conclusions with regard to criteria of the ability of the patient with exophthalmic goiter to withstand the strain of operative therapeusis:

1. During an acute exacerbation of the disease, or in periods of great mental depression, operation is contraindicated.

2. Muscular weakness so great that the patient cannot walk and marked loss of weight with continued loss under absolute rest are serious contraindications.

3. Organic visceral disease so serious as to jeopardize patients' having any operation of similar technical type is a contraindication.

4. Operation should not be undertaken in the presence of an enlarged thymus, until its probable activity has been reduced by irradiation.

5. The Jewish race offers a distinctly higher operative mortality.

6. A metabolism of + 30 introduces a serious risk, which undoubtedly increases with high rates, but not necessarily in proportion, and there is no rate of metabolism which alone contraindicates at least minor surgical procedures.

7. The "vagotonic" type is possibly more vulnerable to the operative ordeal than is the "sympathetico-tonic," but evidence on this point is as yet inconclusive.

8. The minor procedures, whether consisting of injections into the gland, cauterizing or ligating operations, are often most valuable indexes of a patient's resistance to trauma.

In hyperthyroidism, operations will always be attended by a peculiar factor of danger, not present in other operations which are technically similar.

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21. Watson, L. F.: A Method of Controlling Hyperthyroidism, Endocrinology 1:178, 1917.

REPAIR OF BONE FOLLOWING FRACTURES*

JOSEPH A. BLAKE, M.D.
NEW YORK

The repair of bone following injury may seem a trite and worn out subject, yet the mass of clinical material furnished by the war has afforded opportunity for some interesting and practical observations.

During the war, there was considerable controversy, at least in France, on the old subject of production of bone by periosteum; and although I have little to say as to the activity of periosteum as a bone former, I have a strong feeling as to its value as a protector and conservator of developing bone. Portions of bone in gunshot fractures are commonly detached and driven into the muscle. Surgeons have frequently placed bone in the muscles to bridge defects. Invariably, as fas as I know, fragments, not lying in immediate contact with bone, have been gradually absorbed and have disappeared. Quite the reverse happens when bone fragments or grafts lie in close contact with bone. They form new bone almost invariably. Also, the connective tissue of repair seems to be favorable, or at least neutral, to the growth of bone, as observed in the production of osteophytic processes in muscles whose activity is violent enough to produce trauma at their insertion.

These facts suggest that while chemical conditions in the bones are favorable to growth of bone, there are substances found in the muscles which are inimical. If this is so, at least one of the functions of the periosteum may be protective in a chemical sense. The periosteum is of the greatest value mechanically in preserving the attachment of fragments of bone to the soft parts, particularly the blood vessels. In excisions of bones and joints practiced according to the method of Ollier, it carries and supports the thin shavings of bone separated by the rugine, and by transmitting the action of the muscles is one of the chief agents in restoring conformation.

Nutrition is of prime importance in the repair of bone. In fact, one may say that the rate of reproduction of bone is directly dependent on the blood supply. The fact is so evident as to make its statement superfluous, yet most of the failures of operations to unite or graft bones are due to ignorance or indifference on the part of the surgeon in regard to the sources of the blood supply. The errors of the oper-

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* Read before the Pathological Society of the University of Minnesota, Sept. 28, 1920.

ators become more evident if infection occurs. Then not only do grafts and other detached fragments become necrotic, but very frequently the ends of the main fragments, also the line of demarcation corresponding to the point at which the circulation has been interrupted. Frequently, necrosis of the entire ends occurs up to drill holes passed through the medulla. Drilling through the cortex alone, while it may lead to necrosis about the hole, does not seem to be dangerous; but

Fig. 1.—Ununited fracture of the radius six months after injury and three months after a sliding graft operation. Although there was no history of infection immediately following the operation, an abscess formed two and one-half months after the operation, discharging spontaneously under the plaster cast. Density of the bone between the drill holes denoting necrosis may be noted, also the rarefaction, particularly of the distal fragment.

interference with the medulla, the main source of blood supply, is likely in case of infection to lead to complete death (Fig. 1). In other words, inhibition of the blood supply would seem to convert the terminal portions of the fragments into bone which is no better than that transplanted from another source in the patient.

Almost invariably, finely comminuted fractures in which we know a large part of the fragments are absolutely detached, if not infected, unite with remarkable rapidity, the resulting callus being usually excessively large. Every fragment must contribute its quota of new bone in order to produce the amount observed. I have frequently seen similar bone production from chips inserted about a graft or between the ends of the main fragments. I have also observed a new graft, inserted alongside a graft which had been in for six months and had been fractured at its middle, unite at its sides with both fragments of the original graft; the callus of union being visible at the end of three weeks by roentgenography. All of which proves that fragments of bone, even when detached, produce bone if the conditions are favorable.

When sufficient infection is present to change the chemistry of the fluids about the fragments, all detached and anemic portions of the fragments usually die. On the other hand, as we have all noticed, the presence of infection produces hyperemia in the adjacent structures which leads to rapid production (perverted repair) of bone tissue from the portions of bone not killed. In this way, excessive callus is produced. While this excessive repair is distinctly advantageous in many cases in bridging over the defects resulting from extensive necrosis, it often leads to embarrassing flasklike formations about the dead fragments which are sometimes almost impossible to cure if allowed to become pronounced (Fig. 2). The obvious treatment of such conditions is to remove the dead fragments before the cavities are formed. On the other hand, if long defects have to be bridged, it may be wise to conserve the dead fragments rather than to risk interrupting growth of new bone by their removal. Often much judgment and experience are necessary to decide on the proper moment to intervene.

When a portion of bone dies, it preserves its original density, while the remaining living bone becomes softer and less dense because of absorption of its calcareous constituents. Of the causes of this rarefaction, I shall speak later. At present, I desire to call your attention to the difference in density between the dead and living bone as the most valuable diagnostic aid in determining the presence of dead bone. In roentgenography, the dead portion, or portions, throws a much more distinct shadow. This is well shown in Figure 1. In a roentgenogram a dense portion, particularly if it has sharp and irregular contours, separated by a clear interval from the rest of the bone, is certain to be a sequestrum. Sequestra preserve their density for very long periods. I have roentgenographed and removed a number which I knew had been present for many months, and they have always been extremely hard and dense. Although bacteria invade the canaliculi as

found by Kenneth Taylor,[1] osteoclasts do not, and what sequestra lose by absorption is entirely from their surfaces. I am inclined to believe that they are not absorbed at all, for all that I have removed, whether still attached by the living bone or separated for a long time, have always had the sharp points, often long and attenuated, which are characteristic of the line of demarcation. If absorption does occur, these slender points would be lost. The cavities formed about sequestra are rather caused by absorption of the adjacent living bone, especially the involucrum. The latter thus becomes a shell, being continually added to peripherally and absorbed centrally.

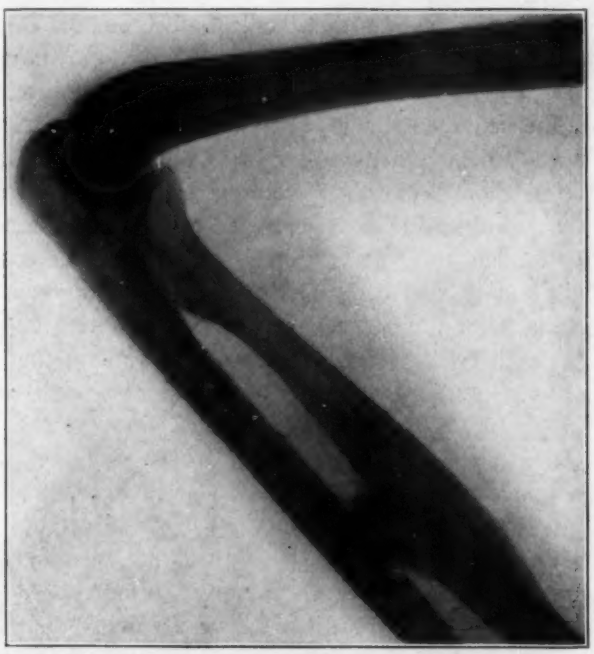

Fig. 2.—Compound fracture of the radius of eighteen months' duration. The end of the distal fragment is almost entirely necrotic. The irregular outlines of the sequestra which are somewhat denser than the involucrum, are outlined by the cavity forming about them. The excessive formation of the callus may be noted. If allowed to remain, the involucrum will be further excavated about the sequestra and a large flasklike cavity will result.

You may ask what happens to fragments of detached bone such as those projected into the muscles in a gunshot fracture if they do not die; for they disappear. My observations lead me to the conviction that they are digested alive either by their own osteoclasts or by the

1. Taylor, Kenneth: The Persistence of Bacteria in Bone Sequestra, Ann. Surg. **66**:522 (Nov.) 1917.

fluids and cells in their strange environment. If they die *en masse,* infection is present and they are discharged with the formation of an abscess or sinus.

I have always found rarefaction present in fractured bones, and I have found that its degree depends more on disuse than on infection. One of the chief etiologic factors in the production of rarefying osteitis as stated in our textbooks is tuberculosis. All surgeons, and I presume pathologists, are familiar with the ease with which the epiphyses of the femur and tibia can be cut in tuberculosis of the knee. Until I had operated on old gunshot fractures in the war, I had believed that tuberculosis was peculiarly productive of rarefying osteitis. In these fractures, I found the same softening of the epiphyses, fully as marked as in tuberculosis, and to a less degree, of course, of the diaphyses. The condition is readily discernible in roentgenograms, especially when compared to roentgenograms of the bones of the sound limbs, but more particularly when roentgenograms taken immediately after the injury and those of a later date are compared. It was also interesting to observe that if the patient was bedridden, rarefaction occurred in the other bones that were not used; but if he were about it occurred only in the immobilized limb. It was also much more marked when the limb was completely immobilized. Rarefaction is accompanied also by decrease in size of the bones. Infection, I do not now believe is so active a factor in producing rarefaction as I had formerly supposed. It seems to act by inhibiting function rather than by any direct toxic factor. In gunshot fractures of the humerus just above the epicondyles, the distal fragments may become almost invisible in the roentgenograms. Delayed union, or nonunion, is very common in these fractures, and rarefaction is more pronounced in such cases, proving that union is dependent on proper nutrition.

It has been my custom to defer operations for nonunion when marked rarefaction of one or both main fragments is present. Obviously an operation, such as inlay grafting, on account of the mutilation necessary in forming a groove, is almost sure to compromise what little circulation remains. It is better in such cases to arrange some sort of apparatus which will permit the patient to use his limb and regain its circulation and nutrition. When an operation is performed in such cases, a sleeve of lamellae of bone chiseled off with the periosteum is better than an inlay graft. A sliding graft should not be attempted, particularly if the bone is a small one, such as the ulna or radius. Inlay grafts from other bones and sliding grafts are indicated when the ends of the fragments are rounded over and the medullary cavity plugged by hard bone (Fig. 3). This rounding over and plugging denotes

repair and coincidently nutrition, and is rarely seen where there is marked rarefaction. In such cases, the channel cut for the graft opens out the medullary cavities, and if the graft is taken from another bone so that active medullary tissue is removed with the graft, success can generally be achieved.

There is another point in regard to the repair of fresh fractures which is of great importance in their treatment. I refer to the rapidity with which repair takes place. Many think that a fracture may be

Fig. 3.—Fracture of the humerus by shell fragments, two years after injury and ten months after an attempt to unite the fragments by means of a graft, which was extruded, the wound having become infected. Complete pseudarthrosis. The rounding over of the end of the proximal fragment and the plugging of the medullary cavity of both fragments by dense bone should be noted.

reduced at any time within the first ten or twelve days. It can be, of course, but if one operates on a fracture on the fourth or fifth or sometimes even the third day, gritty new bone is found around the fragments. This increases rapidly in the next two days and if the fracture has not been reduced this new bone is not only wasted but may

interfere seriously with reduction. Also, the soft parts repair and may prevent reduction. The custom of waiting until swelling has disappeared is a most pernicious one. It developed from the use of the plaster cast, the worst device for treating most fractures, unless used with great judgment and skill, that was ever invented. Of course, a plaster cast cannot be put on before swelling appears because it will become too tight and if put on before swelling disappears it will become too loose. A fracture should be reduced as soon as possible after it has been sustained. Often swelling will be prevented, and, of course, every bit of repair will be utilized effectively. Repair in the sense of forming new bone does not go on indefinitely. Sooner or later it ceases. To treat fractures successfully, it must be conserved and not wasted.

We have found in the treatment of fractures by suspension, together with constant active mobilization by the patient of the contiguous articulations, that the circulation is favored, that swelling rapidly disappears, that repair is rapid, and that marked rarefaction and nonunion are very rare. When splints are used, which is necessary for some fractures, they should be removed at least once, better twice a day, and the patient made to make all the motions allowable for the fracture. The appearance of the limb differs markedly from that customarily observed in treatment by splints with edematous skin with ridges here and there denoting irregular circulation. The muscles retain their form and are not atrophic. As the condition of the soft parts must be an index of that of the bony structures, it is reasonable to suppose, as seems to be proved clinically, that the circulation in the bone is far better than that obtained when the limb is kept quiet in splints. Manifestly, with better circulation, repair must be more active and there must be less tendency to necrosis of fragments devitalized because of their circulation's being cut off by traumatism or by later infection and thrombosis. Furthermore, suspension allows access to the limb for frequent dressings with the least disturbance to the fracture, which permits of better treatment and therefore quicker consolidation. Also not the least advantage of suspension in promoting circulation is the quicker sequestration of dead bone and the earlier opportunity for its removal before disagreeable callus forms.

Although nothing new has been discovered during the war in regard to the morphology of the repair bone yet much has been learned in regard to what we may expect in the formation of new bone and also in the treatment of dead bone, especially in regard to the period when it should be removed. As I hope I have made clear, it should be removed in most instances as soon as it becomes detached. In exceptional cases when it is desired that exuberant callus be formed

to bridge over defects, it may be wise to leave in sequestra which bridge defects until the rapid callus formation which goes on about them has completed the continuity of the bone. Attention has been called to the use of dead bone for the promotion of repair by Heitz-Boyer.[1] He has called attention not only to the production of new bone about grafts which have died on account of infection, but also to the stimulation caused by the introduction of dead bone from other sources. The conservation, therefore, of dead bone becomes of real practical value in many cases.

Before concluding, I should also call attention to the question as to when newly formed bone can bear the strains of use without deformation. This is of great practical importance in fractures of the femur in which the use of the limb necessitates weight-bearing, that is, a compressive force at the point of fracture. It has been found that it is not safe to allow weight-bearing on the fractured femur until the newly formed bone has established its adult condition with the formation of haversian canals. The reestablishment of the haversian system can be determined by roentgenograms.

1. Heitz-Boyer: Tr. Cong. franç. de Chir., 1919.

TREATMENT OF FRACTURE OF THE FEMUR*

KELLOGG SPEED, M.D.
CHICAGO

SERIES OF FRACTURES OF THE FEMUR REPORTED IN RECENT AMERICAN LITERATURE

Nis reported 575 cases of simple fracture of the femur occurring in the Charity Hospital at New Orleans during ten and one-half years. Of these fractures, ninety-six, or 16.7 per cent., were of the neck of the femur. He found that fractures of the neck were rare in negroes—only fourteen of the ninety-six patients being of this race. There were fifty-six males and forty females. The age incidence in ninety-four cases of fracture of the neck of the femur in this series is recorded in Table 1.

TABLE 1.—AGE INCIDENCE IN FRACTURES OF THE NECK OF THE FEMUR

Age	Number of Cases
1- 10	0
10- 20	7
20- 30	1
30- 40	6
40- 50	7
50- 60	15
60- 70	29
70- 80	20
80- 90	8
90-100	1

No two surgeons of the hospital agreed as to the method of treatment of these fractures. There was not one attempt at complete reduction and restoration of normal function. If patients survived and left the hospital, the usefulness and function of the leg was not investigated. Only two or three patients were given anesthesia and placed in plaster-of-Paris casts, with the limb in abduction. Most of the casts applied were removed within a few days, probably on account of pain, and Buck's extension was thereafter used as the method of treatment. The methods of treatment employed were: Buck's extension in 35.2 per cent. of the cases; plaster of Paris in 29.8 per cent.; extension, cast six weeks, 10 per cent.; Liston's splint, 9 per cent.; Hodgen's splint, 8 per cent., and sand bags, 8 per cent. The mortality in ninety-six fractures of the neck was 15.6 per cent.; and of the fifteen patients who died, fourteen were more than 60 years of age.

Martin published the end-results of 242 cases of simple fracture of the femoral shaft, collected from the hospitals of the city of Philadel-

*Based on a report made before the Société Internationale de Chirurgie, Paris, July, 1920.

phia. Most of these fractures were treated by Buck's extension. Two of his conclusions were:

No. 12.—The unsatisfactory results following the weight extension treatment of simple fracture of the femoral shaft in adults suggest that this method is either inadequate in itself or is unskilfully applied.

No. 13.—Efforts to obtain better results should be directed to (a) employment of more weight to entirely overcome the deformity; (b) early resort to open operation if extension seems insufficient; (c) systematic use of massage and passive motion continued for months; (d) longer use of crutches than is now customary, and (e) education of the patient.

Estes analyzes the reports of 739 cases of fracture of the femur. The age distribution in fractures of the shaft of the femur in this series is given in Table 2.

TABLE 2.—AGE DISTRIBUTION IN FRACTURES OF THE SHAFT OF THE FEMUR

Age	Number of Cases
0-10	90
10-20	65
20-50	122
50-70	55
70-90	12
Total	344

TABLE 3.—AGE DISTRIBUTION IN FRACTURES OF THE FEMUR

Age	Number of Cases
0- 10	125
11- 20	48
21- 30	26
31- 40	23
41- 50	53
51- 60	73
61- 70	77
71- 80	69
81- 90	26
91-100	5
101-110	1

He concluded that during the period of hard active labor there was the greatest number of fractures of the shaft of the femur in America. Speaking of fractures of the middle third, he says: "Except in selected cases I have quite lost my preference for traction methods of treating these fractures, since skiagrams so frequently showed me overlapped fragments, inaccurate apposition and nearly always a little angulation as a part of the result."

In 1890, the fracture committee of the American Surgical Association agreed that if the end-results after fracture of the femur should be considered good there must be: (*a*) firm bony union; (*b*) correct axial relations of fragments; (*c*) maintenance of correct relations of

the anterior planes of upper and lower fragments; (*d*) no shortening to exceed ⅛ to 1 inch; (*e*) no lameness occurring as a result of shortening over 1 inch, and (*f*) an understanding that conditions attending the treatment may prevent these satisfactory results. At that time, this committee reviewed 364 nonoperated cases, in 67 per cent. of which there were good anatomic and functional results.

FRACTURES OF THE FEMUR AT THE COOK COUNTY HOSPITAL, CHICAGO

From the records of the Cook County Hospital, Chicago, for the last three years, I have collected the reports of 526 cases of fracture of the femur, which were observed long enough to warrant their inclusion in this article. Four of the series were compound fractures. The age distribution is given in Table 3.

There were 328 males and 198 females. The right femur was affected in 271 cases; the left in 255. The incidence according to the part of the femur affected is given in Table 4.

TABLE 4.—INCIDENCE OF INJURY IN VARIOUS PARTS OF FEMUR

Site of Injury			Number of Cases	Per Cent.
Neck			124	24
Intertrochanteric			118	22
Greater trochanter			10	2
Subtrochanteric			14	2.5
Shaft	upper	39		
	middle	157	249	47
	lower	53		
Supracondylar			5	1
Condyles			2	1
Intercondylar			1	0.3

Mortality of Fractures of the Femur.—The total deaths of the series were fifty-six, 11 per cent. Twenty-two deaths were attributed to pneumonia complicating the fracture. Other causes of death were multiple fracture, nephritis, myocarditis, infection and lung abscess. The number of deaths occurring in the different fractures is given in Table 5.

TABLE 5.—NUMBER OF DEATHS OCCURRING IN DIFFERENT FRACTURES

Site of Injury			Number of Cases	Per Cent.
Intertrochanteric			22	18.6 of all intertrochanteric fractures
Neck			20	16.1 of all neck fractures
Shaft	upper	2		
	middle	4	7	
	lower	1		
Subtrochanteric			3	
Supracondylar			1	
Greater trochanter			1	
Not stated			2	
Total			53	

Methods of Treatment.—The methods of treatment for the whole series of 526 cases were: rest in bed, sand bags, sitting up in bed supported by pillows, etc., in 35 cases; Thomas splint with suspension traction in 25 cases; vertical extension in children in 56; Buck's extension, sometimes combined with Liston's splint, double inclined plane and molded plaster-of-Paris splints in 97; fracture table, extension and cast in 113, or 21 per cent.; splints of plaster and wood in 8, and treatment not stated in 192, or 36 per cent.

Discharge Results.—The results on discharge from the hospital were: shortening, ½ to 2½ inches, in 101 cases; left hospital on crutches, 189; left hospital in cast, 39; able to walk, 51; nonunion (questionable), 6, and discharge condition not stated, 240, or 47 per cent.

Operations on Fractures of the Femur.—The total number of operations performed to reduce these fractures was fifty-one, divided as in Table 6.

TABLE 6.—Operations and Results

Operation		Number	Results	
Site	Type		Good	Bad
Neck	Bone peg	5	2	3
Neck	Steel screws	6	2	4
Shaft	Steel plates	15	6	9
Shaft	Intramedullary bone pegs	11	7	4
Shaft	Metal screws	1	..	1
Shaft	Simple replacement	3	3	
Shaft	Calipers	7	5	2
Shaft	Nail extension	2	1	1
Shaft	Parham's band	1	1	

Mortality Following Operation.—The total deaths following operative interference were 4, or about 8 per cent.: neck, metal screws, 2; shaft, intramedullary bone peg, 1, and shaft, nail extension, 1.

SUGGESTIONS FOR STANDARD TREATMENT

The results tabulated here are not good. In an attempt to improve the results I make the following suggestions:

Indications for Fixation and Traction.—In the general consideration of treatment it is acknowledged that the femur is richly supplied with strong muscular attachments, and consequently a reduction of fracture in any part of its continuity cannot be obtained by simple fixation of the thigh. In addition to fixation, there must be traction to obtain relaxation of the muscles which have become infiltrated with blood to a certain degree, following the trauma. The infiltration causes muscle shortening and pull on the bone, holding it out of normal alinement, *once it is broken.* Traction in the axis of normal muscle action and weight-bearing overcomes muscular contraction and puts the muscles at rest, just as fixation puts the broken ends of the bone at rest. When

DRS. RICHARDS, IRVINE, RIDGES, SNOW & TYREE

these two indications are met, we are treating the fracture properly, but an effort must be made to obtain the best ultimate function of the limb. Hence we must restore the bone to its normal physiologic axis and secure bony union and bone integrity to assure both a structural and functional restoration. Consequently, proper methods of treatment demand precision and system. *The patient with a fractured femur should be hospitalized.* Roentgen-ray examination with reduction and splinting should be made at once, so that a maximum muscle infiltration and contraction will not occur and so that bone fragments may be approximated and immobilized.

General Law of Fracture Treatment.—The distal bone fragment over which the surgeon has control must be brought into a plane of normal relation with the proximal fragment. When this practice becomes general, both the suffering and mortality incident to fractures of the femur will be greatly lessened. In aged patients, some of the mortality is the result of the so-called conservative methods of treatment which lead to pain and which wear out the patients' strength and resistance, so that they succumb easily.

Treatment of the Fracture of Different Parts of the Femur.—Suggestions for standard specific treatment of fractures of the femur may be divided according to the site of fracture, thus—neck, intertrochanteric, subtrochanteric, shaft, supracondylar, epiphyseal separation, and condylar.

FRACTURES OF THE NECK

Of the 124 cases of fracture of the neck in our series, seventy-two were in females and fifty-two in males. Among the twenty deaths after fracture of the neck, only six were in males. This would make it appear that the probability of fatal issue in females was greater than in males after fractures of the neck. The average age of the six males who died was 68; of the fourteen females, 61 years. Only five of the deaths occurred in patients under 60 years of age. Distribution of the neck fractures according to age is given in Table 7.

TABLE 7.—DISTRIBUTION OF FRACTURES OF THE NECK OF THE FEMUR ACCORDING TO AGE

Age	Number of Cases
1–10	2
11–20	0
21–30	3
31–40	4
41–50	23
51–60	28
61–70	27
71–80	26
81–90	10
91–100	1

Fractures of the Neck in Childhood.—Fracture of the neck occurs in childhood frequently, and was first thoroughly described in America by Royal Whitman in 1890. An early diagnosis is highly desirable because reduction should be made at once. Many of the fractures of the neck in adolescents are epiphyseal separations with little displace-

Fig. 1.—Healed neck fracture, with coxa vara from too early unsupported weight-bearing. This illustration and Figures 4, 7, 8, 10, 12 to 25, 32, and 37 to 42 are adapted from the author's textbook, "Fractures and Dislocations," Lea & Febiger, Philadelphia, 1916.

Fig. 2.—The usual type of neck fracture of the femur with a minimum amount of shortening, foot rotated outward. When this fracture was reduced the roentgenogram revealed almost perfect neck angulation and apposition of fragments.

ment. The causative trauma may be overlooked. The child, unlike an adult, may walk away from the scene of the accident, and the gradual displacement accompanying the change in the angle of the femoral neck with shortening frequently follows, as the patient bears weight on the injured leg (Fig. 1). Some process of repair accompanies the gradual displacement of the shaft upward. If the diagnosis is not made early, the neck may be molded, after several weeks, into a firm bony mass, which then requires open operation to effect a perfect reduction.

Technic of Reduction.—If the fresh fracture has resulted in complete separation, either through the epiphyseal line of the neck or at

Fig. 3.—Fracture of the neck of the femur involving the head, the usual displacement. It is perfectly evident that there is shortening, rotation outward of the foot and change of the normal axis (130 degrees) of the femoral neck, and that extension, internal rotation followed by complete abduction of the thigh are necessary to effect a proper relation of fragments.

the base of the neck, the shaft usually is moved upward, backward and outward (Fig. 2). Hence to appose the fractured surfaces, the distal portion of the limb over which the surgeon has control must be lifted forward, rotated inward and then must be drawn down to normal length (Fig. 3). This is followed by ***abduction to the limit,*** so that the greater trochanter is apposed to the rim of the acetabulum and the side of the pelvis and the neck is brought into alinement and contact with the head, aided partly by the capsular ligament and the resistance of the head against the acetabulum. The angle of the neck is thus restored (Fig. 4).

Result of Restoration of Angle of the Neck.—In this position of extreme abduction, the security of the reduction is assured by the capsule, the bony contact and the muscular impotence incidental to the position. Because the range of abduction in the human hip depends on the normal angle of the femoral neck to the shaft, this reduction in a position of extreme abduction looks toward a perfect reestablishment of the angle of the neck. If that is secured, there is no insecure support of the hip later, no shortening and no compensatory distortion of the pelvis is required to accommodate for a changed angle of the neck.

Body Casts and Hip Spicas of Plaster of Paris.—While the leg is in extreme abduction, the patient is placed in a plaster-of-Paris cast

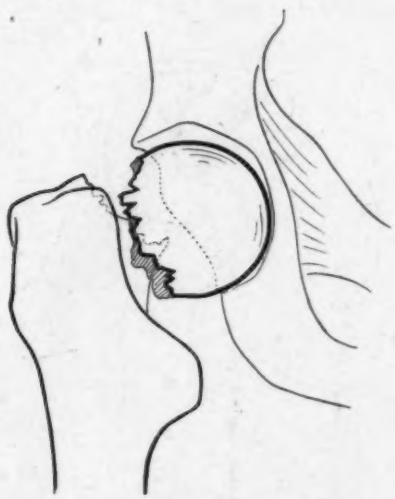

Fig. 4.—Attempted reduction by extension in a straight line. Some length has been regained, but the neck angle is still about 90 degrees and can be corrected by complete abduction. Healing in the position shown would lead to an adducted leg and some shortening.

(Fig. 5), extending from the nipples to the toes, for from eight to twelve weeks, and is not allowed to bear weight for from three to six months thereafter. He must use a walking caliper fitted into the shoe during this period to avoid subsequent development of coxa vara.

The technic of application of the body cast requires that all bony points should be completely padded to avoid pressure necrosis and that the plaster should be well reinforced at the weak points, namely, at the groin and outer aspect of the thigh up to the waist. For padding purposes, I have found that saddler's felt is the best material. The usual cotton or stockinet wadding is used to cover the patient, and the saddler's felt padding is applied in addition. Nine pieces, each about 6 inches square, are required. One is placed over each anterior superior

iliac spine, one over the sacrum between the sacrum and the sacral support, one on each lateral aspect of the knee to be included in the cast and one on each side of both ankles to soften the force used in extension and traction on the fracture table. Multiple layers of plaster bandage are applied longitudinally over the front of the groin and the lateral aspect of the thigh to give strength. This additional strength makes tipping of the patient in the cast, for hygienic purposes and necessary change of position, safe. A fairly large sized pad is placed over the epigastrium (dinner pad) before the cast is applied. This allows room for distention after eating, without unpleasant pressure.

Fig. 5.—Woman, aged 52 years, with fracture of the neck of the femur in body cast. Both legs abducted. The feet are off the edge of the bed on either side, and a more than half sitting posture is possible. She can be turned on her side or even onto her face safely. The cast reaches down to the knee on the uninjured leg. By the pole above the bed, she can move the upper part of the body at will.

After-Treatment—the Walking Caliper.—The walking caliper is made like a Thomas leg splint with a snug fitting thigh ring. The lower ends of the iron side-bars are turned in at right angles and fitted into the heel of the boot, the hole in the boot being of such length that in walking the patient's weight is supported largely by ring pressure against the tuberosity of the ischium. Calipers can be made with adjustable side rods, and they are strapped to the leg by broad canvas

bands (Fig. 6). When the patient goes to bed, the calipers are removed, because the soft callus does not have to support weight.

Treatment of Fractures of the Neck in Adults.—The same treatment is applicable in fractures of the neck of the femur in adults, whether impacted or not, unless the physical condition of the patient precludes any active treatment. It should give a high average of successful results. There is little doubt that nonunion will seldom occur if this careful approximation of fragments is attained. The capacity for

Fig. 6.—Patient in walking caliper after cure of fracture of neck of the femur. Straps hold the leg firmly and the leather ring presses against the ischial tuberosity when the patient bears weight. The length is adjustable by means of the threaded bar and lock nuts.

repair in bony tissues in adults is not so great as it is in children; but still it is active, as evidenced by bony union following open operation on ununited fracture of the femoral neck, where simple freshening and fixation of fragments in apposition is the only operative work performed. The cast is most frequently applied with the patient anesthetized, lying on a fracture table.

Rationale of Abduction Treatment for Fractures of the Neck.—The position of extreme abduction offers the best chance for mechanical apposition of fragments, and that appears to be more important than the blood supply of the head fragment, when ultimate bony union is considered. In this position, the greater trochanter and neck come into close relation with the upper border of the acetabular rim. The Y ligament also assumes a position where it exercises its greatest strength and function, being used as a suspensory fulcrum, on which the major fragment (shaft) is swung outward and into direct contact with the head fragment, on which a direct hold cannot be obtained. After recent fracture of the neck, whether through its narrow or broad portions, this method of treatment approximates satisfactorily the fractured surfaces, and immobilization in the abduction position results in bony union (Fig. 7).

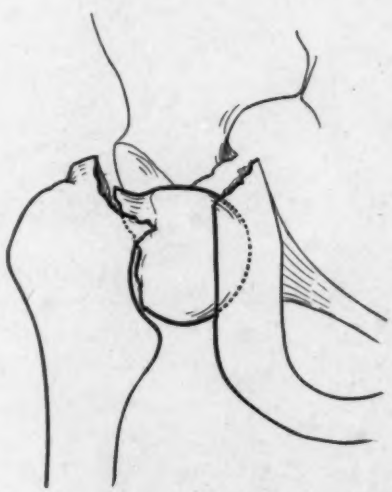

Fig. 7.—The pelvis may be broken along with the femoral neck fracture. The neck angle is less than 90 degrees.

Treatment of Old Fractures in Adults.—In old fractures, however, even where the head fragment is levered into position, it may be difficult to maintain bony contact (Fig. 8). Shortening of the neck, caused by bone absorption from the irritation of motion and use and incomplete reduction, becomes so great that the trochanter impinges on the acetabular rim during abduction and hyperabduction; it may cause a separation of the fragments, rather than a forced contact. Consequently, in old fractures, in order to secure a bony union, it has been considered best to introduce a bone peg through the trochanteric region into the head, while the limb is in a position of extreme abduction. I have

treated a few patients, whose cases are classed under this head, in whom simple freshening of the fragment surfaces near the hip joint, without the introduction of a bone splint, followed by a sufficient period of immobilization in abduction, resulted in bony union. If the head and neck are so much absorbed that a fragment of only from 1 to 1.5 cm. in thickness remains, certain operative methods are necessary if a weight-bearing, painless hip is secured. Either an autogenous bone peg can be driven clear through the head into the acetabulum making a bony ankylosis, fulfilling the conditions mentioned, or the head may be excised and the freshened neck and acetabulum placed in apposition with the thigh in abduction, a bony union being desired (Fig. 9). Tilting of the pelvis will accommodate for much of the shortening, and the bony union will be painless. The necessary factor after operation is the firm

Fig. 8.—Fracture of the femoral neck which had gone untreated for some time. Absorption of the neck and head fragment, adduction of the leg and shortening and rotation of the foot outward are apparent. The abduction position in this type may lead to bony union; more often operation is indicated.

body cast applied while the patient is on a fracture table, with the *thigh in complete abduction,* with the foot rotated inward. If the patient cannot tolerate rest in bed even in the half sitting position that such a cast permits, abduction and extension by the Thomas or Hodgen splint, with rotation of the thigh inward, will also be impossible. If these methods are not applicable, the patient must then be placed in a wheel chair or set up in bed. The result will be a fibrous union of the shaft to the pelvis, which will permit the maximum of shortening when weight is borne on the limb. The pain in such a hip may eventually become bearable, but usually the function is very poor.

Results in Fractures of the Neck.—Probably not more than 15 per cent. of fractures of the neck in adults result in bony union, unless the

patients are treated by extreme abduction (Fig. 10). Originally impacted neck fractures, let alone and not broken up nor brought into reduction and abduction, result, if union obtains, in a short, adducted and outwardly rotated leg. To avoid the bed confinement in a supine position, Moore advised a modification of the Whitman method by the application of the cast with the thigh in abduction, while the patient is in a sitting position. He treated sixteen patients thus, nine of whom were more than 70 years of age; seven had good functional results, one died, two had nonunion, two were not traced and three were still under treat-

Fig. 9.—Bone transplant into the pelvis through the femur and broken off head. This patient was more than 50 years old and had had this fracture of the neck of the femur for two years. The neck angle has been well restored, the hip is in maximum abduction and the patient now has a weight-bearing, painless, stiff hip joint.

ment. When the ordinary body cast is properly applied the patient can easily assume a half sitting posture (Fig. 5).

Extension Without Abduction in Neck Fractures.—Buck's extension and extension by a Thomas or Hodgen splint with traction and suspension fail to consider the degree of abduction necessary to restore the angle after fracture of the neck. If one leg is drawn into abduc-

tion in these suspended splints, the angulation is not steady because the patient's pelvis is not fixed. The patient consequently can, and does, tip the pelvis to overcome the abduction. Putting both legs in extreme abduction in a suspended Thomas splint or Sinclair's net bed will secure the necessary abduction, but the bed confinement is as severe as that induced by a cast. The same arguments apply to caliper extension (Fig. 11).

Résumé of Treatment of Fractures of the Neck.—The best treatment of fractures in youth or other age is immediate reduction and use of the position of extreme abduction in a plaster-of-Paris body cast. After the patient is etherized, the trochanter is lifted up, the foot is rotated inward, and the leg is drawn down to the fullest extent. Then it is swung out into extreme abduction while still under traction. This procedure is most easily carried out while the patient is on a fracture

Fig. 10.—Fracture of the femoral neck with impaction. Shortening, adduction of the leg and change of the neck angle are all present. Abduction treatment in a plaster spica would promise a much better result than a "leave impaction alone" treatment.

table. It is almost impossible to secure permanent, proper abduction with restoration of the angle of the neck by any other means. If the patient's health will not permit the use of a plaster cast, it will also preclude the use of any traction which requires bed confinement. Therefore, since no half-hearted method of traction will secure bony apposition and lead to bony union, the only other treatment, which is really no treatment, is sitting up in bed or in a wheel chair supported by pillows.

Impacted Fractures of the Aged.—In the aged, who cannot tolerate the cast abduction treatment, any impaction of fragments should be let alone. The fragments usually slip apart in a few days after rest in bed.

Patients Suffering from Delayed Treatment.—If the patient is not seen for many days after a fracture and a maximum of shortening, combined with some bone absorption in the neck has followed, the abduction and cast method should also be used. Should neck absorption be great enough to lead the surgeon to fear delayed or nonunion, the patient should be subjected to immediate operation, an autogenous bone peg being passed through the trochanter up into the head with the neck angle

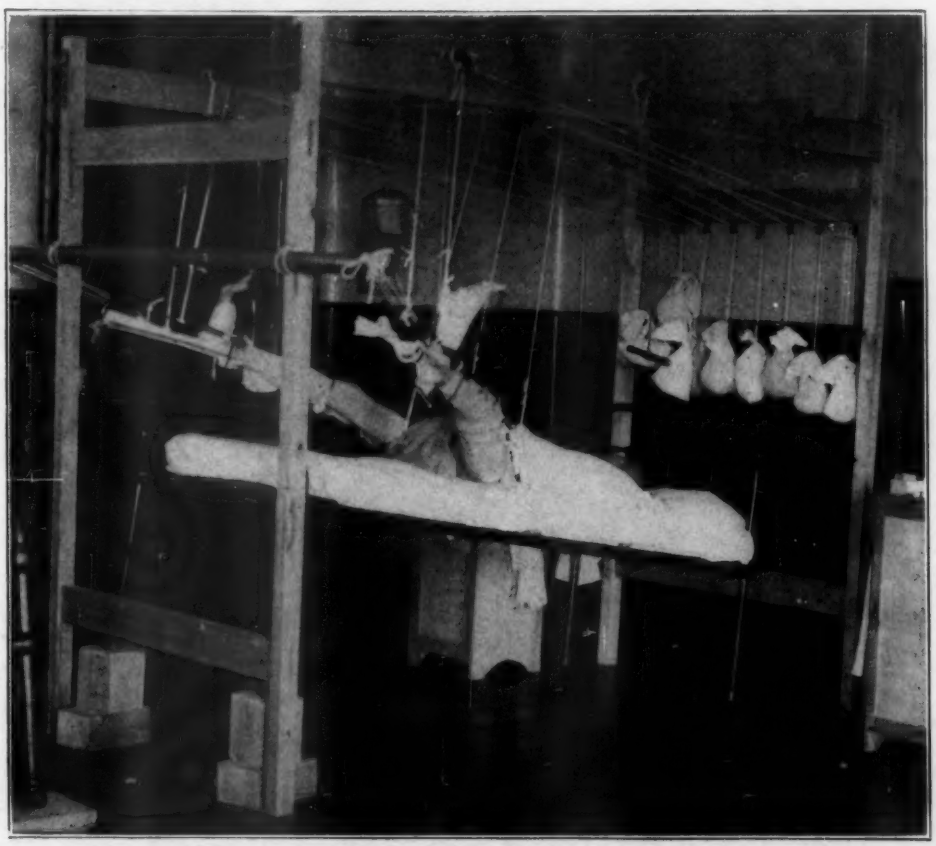

Fig. 11.—Double suspension traction in abduction. By this means abduction of the thigh can be maintained. For fractures of the neck of the femur we prefer the plaster spica or cast, allowing the patient to sit up.

restored. Exogenous bone and metal screws or nails should never be used in the neck of the femur. Any successful cases that have been reported following the insertion of nails or screws in the femoral neck for fracture may be attributed to the immobilization and to a position of abduction maintained during the healing, and occurred *in spite* of the foreign body present.

Vicious Union—Coxa Vara.—The most common deformity requiring treatment after vicious union of fractures of the neck of the femur is coxa vara. The neck is shortened, thickened and painful when weight is borne; its angle with the shaft has been reduced to 90 degrees or less, and the shortened adducted leg gives evidence of deformity. For these patients, an osteotomy alone promises a better result. If the thickened neck still permits free hip motion, one may cut across the neck and swing the leg out into extreme abduction and inward rotation under strong traction, hoping to gain a better neck angle and better function. If there is bony union between the neck and head and the pelvis with an adducted leg, one can improve the function by

Fig. 12.—Impacted fracture healed with adduction and limited motion. Exostosis at acetabular border.

performing a subtrochanteric osteotomy, swinging the leg into abduction and letting it unite in this position (Fig. 12).

UNUNITED FRACTURES OF THE NECK

Ununited fractures of the neck of the femur demand treatment when the patient desires to be relieved of the disability, usually shown by shortening, adduction of the leg, lameness, the necessity of using a crutch or cane and pain.

Some Causes of Nonunion.—There is no doubt that most instances of nonunion or malunion could be avoided if the adequate primary treatment of extension and abduction outlined were applied after an early correct diagnosis. When true nonunion has occurred no manipu-

lation method will cure; surgical operation alone can give bony union. Some patients treated by the proper method are allowed to bear weight too soon; coxa vara or even a breaking down of the soft callus may result with all the findings of a nonunion. No patient after fracture of the neck of the femur should bear weight on the bone for six months; he should wear a walking caliper.

Treatment of Ununited Fractures of the Neck.—A series of 120 cases of nonunion of hip fractures was reviewed by Henderson. There were sixty-eight males and fifty-two females. Twenty-six were operated on with no deaths, ninety-four were dismissed without treatment. Nails or screws were used in eight cases; bone transplants in eighteen cases. Only two operative wounds were infected. The fibula was used as the graft, and every care was taken to restore the angle of the neck.

Fig. 13.—Old fracture of femoral neck treated by nailing. Because the nails projected into the acetabular cartilage and caused pain, they were removed eighteen months later. The neck had not united.

Full exposure was made by a U-shaped incision with removal of the greater trochanter. All patients were on a fracture table, and after operation were placed in plaster-of-Paris casts. The end-results in seven cases were not known; ten operations were successful; eight were failures. The percentage of good operative results was 38, but of the entire series of 120 patients only 8.3 per cent. were improved. It was concluded that any means, in suitable cases, which will freshen the fractured surfaces and maintain them in apposition (abduction and traction) are sufficient. I agree with that conclusion, and believe that the value of the autogenous bone peg inserted through the neck into

the head has been overrated. Some operators use two incisions, one over the trochanter through which to insert the peg, another over the femoral neck just outside the great vessels, to freshen the fragments and give a proper guide to the bone peg as it is inserted. Traction and extreme abduction are required on a fracture table during the operation.

A series of eight cases of nonunion of the neck of the femur treated by the insertion of nails was reported by Swett. He made a lateral incision only, making no attempt to freshen the fragments. The results were not satisfactory (Fig. 13).

Absorption of the Femoral Neck.—When the neck fragment has been absorbed by use and improper treatment and when the head is

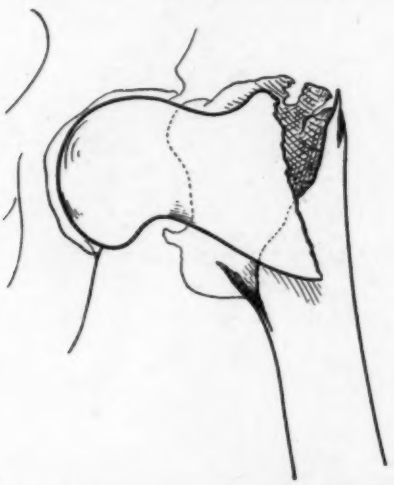

Fig. 14.—Intertrochanteric fracture. The changed neck angle and the large surface of cancellous tissue which insures bony union may be noted. Abduction plainly indicated.

atrophied so that only the articular portion, which does not project beyond the acetabular margin, remains, it is difficult to bring the fragments in apposition.

Viability of the Head of the Femur.—It has always been asserted that the state of nutrition of the head fragment is also a point to be decided. Even if it does not bleed when scraped, it may be viable and conditions favorable to full return of life must be established. A head which has thus been long separated from the shaft is somewhat softened, yellow and contains little holding substance into which a bone transplant can be driven. In the old cases, the use of the graft as a carrier of osteogenetic stimulus is futile unless there is also firm apposition of fragments. It is hardly reasonable to expect

the transplant, which must first be partly renourished by the shaft portion, to save the life of the soft head fragment. Bone regeneration must be developed in the bridge of the transplant and by it carried into bone partly dead. Consequently, some operations for nonunion of the neck by means of a bone transplant will not succeed. If the head in these old cases is considered as a sequestrum, it may become vitalized if grafted on living cancellous bone.

Brackett and New have advised placing the head of the femur on the inner, upper side of the sawed off and freshened trochanter, which is abducted enough to come into contact. After the leg had been in a plaster-of-Paris cast for ten weeks they obtained seven good results in nine cases in which this operation had been performed. The unions

Fig. 15.—Intertrochanteric fracture with separation of the lesser trochanter and tearing of the acetabular rim. Abduction is plainly indicated in the treatment.

were strong and bore weight well; the amount of motion in the hip was not complete but was practical.

Operative Treatment.—My treatment has been as follows:

If there has not been great absorption of the neck, the fragments are freshened through an anterior incision and an autogenous bone peg is then inserted from the trochanter into the head, while traction is maintained and the extremity is abducted and rotated inward. In patients over 50 years of age in whom the hope of bony union of the head to the neck is diminished, it may be better practice to produce an ankylosed hip by driving the bone peg clear on into the pelvis. This promises a stiff hip which bears weight painlessly, which demands a

shorter bed and cast confinement. This bone transplant ankylosis operation is more quickly performed than excision of the head, and it is less of a shock to the patient. However, as stated, I am beginning to doubt the value of the bone transplant. When the head is largely absorbed and fragmented, the best treatment is its excision with freshening of

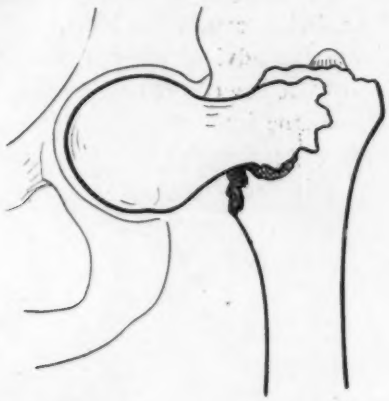

Fig. 16.—Intertrochanteric fracture with shortening and changed neck angle, indicating extension followed by abduction to restore normal position.

Fig. 17.—Intertrochanteric fracture with little displacement, but one which requires abduction.

the bony surfaces, so that when the limb is drawn down and completely abducted, bony ankylosis in that position results. Brackett's operation is more extensive; it must be reserved for younger and more active patients for whom length of limb and hip joint motion are very essential.

INTERTROCHANTERIC FRACTURE

Intertrochanteric fractures mostly result from direct violence. The plane of fracture runs diagonally from one trochanter to another, and either or both trochanters may be broken off and separated. The great proportion of these fractures makes their treatment important. Many occur in patients who lead an active life and have need of good leg function. The displacements vary—usually there is little shortening, ½ to 1 inch; but the neck angle is reduced from 130 degrees to about 90 degrees in most instances (Figs. 14 and 15). Traction will easily restore full length, and the swinging out to full abduction restores the neck angle. A body plaster-of-Paris cast applied while the patient is on the fracture table in this position gives excellent

Fig. 18.—Intertrochanteric fracture involving both trochanters. The changed angle between the shaft and neck fragments may be noted.

results. If there is impaction and the patient cannot be confined to bed, sand bags or pillows and a sitting position will frequently give a satisfactory result but with some shortening (Figs. 16 and 17). Nonunion of this portion of the bone is rare, because of the large cancellous surfaces which come in contact. Bony union results even when no mobilizing treatment is employed (Fig. 18).

However, our statistics show a higher mortality from this fracture than from fractures of the neck, and we advise great care of the heart and lungs of these patients. Many are very fat, with corresponding cardiac weakness. Prolonged anesthesia should be avoided. If union should fail, an autogenous bone peg or a simple freshening of the bone surfaces is all that is needed operatively before a cast is applied. A walking caliper is required for six months to avoid coxa vara.

TROCHANTERIC FRACTURES

Fractures of the trochanters alone do not often demand unusual treatment. If the greater trochanter is widely separated by the attached muscles, it may be pegged onto the rest of the bone and the leg immobilized in abduction. Usually abduction or rest in bed for two or three weeks gives a useful leg (Fig. 19). Fracture of the lesser trochanter alone is rare. Because the separated fragment is pulled up and inward, it is sufficient to treat the patient by setting him up in bed, with the thigh flexed on the body, for three weeks. Casts are rarely required to maintain this position (Fig. 20).

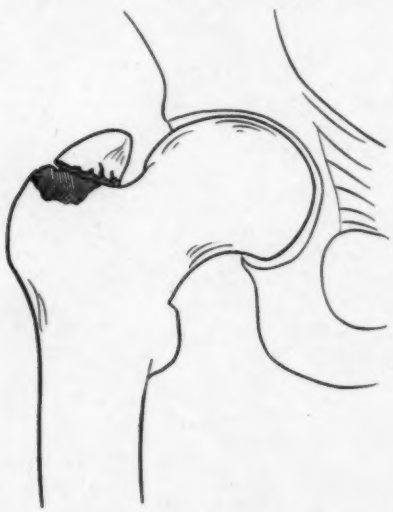

Fig. 19.—Fracture of the greater trochanter.

SUBTROCHANTERIC FRACTURES

Subtrochanteric fractures are not frequently encountered; but they are very important inasmuch as the relative angle of the neck is lessened and shortening occurs. The distal or shaft fragment may be displaced above the level of the acetabulum. These fractures are often short spirals or oblique. It is often most difficult to reduce the deformity and to maintain the fragments in apposition. The two fragments are of unequal lengths: the proximal or upper fragment which is very short contains the head, neck, trochanters and a varying length of shaft up to 2 inches. It is strongly flexed and abducted by attached muscles (Figs. 21 and 22). The distal fragment consists of the remainder of the femur pulled on by all the strong thigh muscles including the quadriceps extensor. The proximal fragment has varying displacement depending on the type of fracture, the cause—direct or

indirect violence—and the pull of the glutei, ilio-psoas and pelvic muscles.

Treatment of Subtrochanteric Fractures.—The best method of treatment is continuous suspension traction with the Hodgen or

Fig. 20.—Fracture of the lesser trochanter.

Fig. 21.—Spiral subtrochanteric fracture. Shaft fragment drawn in and up; trochanter rotated outward.

Thomas splint bent at the knee. The large fragment is swung out and up to meet the prolonged axis of the short upper fragment, and at the same time strong traction in that axis must be made to pull the end of the lower fragment into proper relation with the

upper. Because the long fragment tends to be adducted, it may be necessary to apply direct outward push against its upper end by means of a pad on a threaded bar attached to the side of the main splint. Lateral traction by adhesive is often used. All these methods may fail to give complete reduction. Thomas splints with attachment for knee movement are very useful.

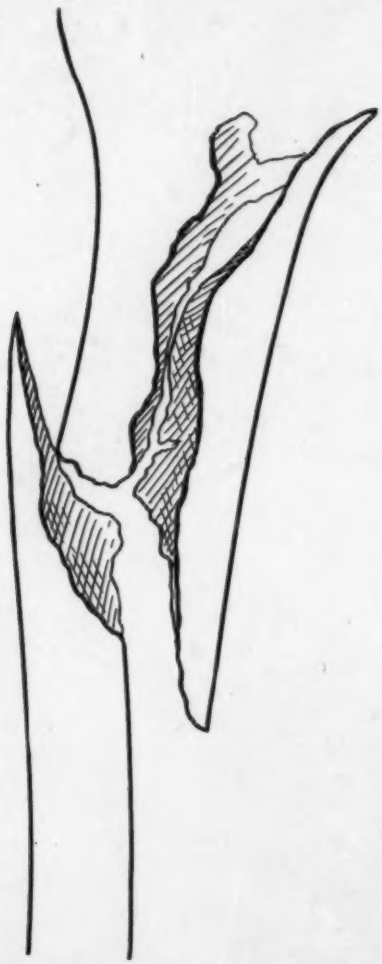

Fig. 22.—Subtrochanteric fracture with triangular fragment. A reduction of this type is difficult to obtain and hold. Extension and abduction of the lower fragment is indicated.

Operation for Subtrochanteric Fracture.—Should reduction fail after six or seven days' effort, as shown by roentgenographic control, operation is indicated. An operative reduction may be difficult, and it may be even more difficult to maintain the reduction during the applica-

tion of an internal splint. The upper fragment is so short that a metal or other plate cannot be attached. When there are spiral fractures, a band or an ivory screw may maintain the reduction. Intramedullary splints do not hold well (Fig. 23). When the deformity tends strongly to reproduce itself, the muscular insertions into the greater trochanter may be loosened by a sharp chisel, or the tendons may be severed so that the upper fragment does not tend to rotate outward so strongly. Reduction may then be accomplished easily.

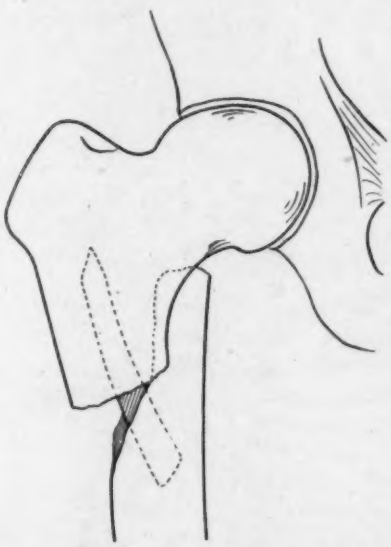

Fig. 23.—Attempted reduction of subtrochanteric fracture by an intramedullary bone peg according to Hey Groves method (*The Journal A. M. A.*, Sept. 6, 1919, p. 742). Little reduction obtained anatomically. The peg was too short and the lower fragment was not sufficiently extended and abducted. A fair functional result followed this repair.

FRACTURES OF THE SHAFT OF THE FEMUR

These occur in any part of the diaphysis, the limits being from just below the lesser trochanter proximally to a plane just above the condyles distally. There are the usual types of transverse or oblique fractures caused by direct violence, resulting frequently in comminution or the freeing of a triangular shaped piece of bone, and the spiral fracture caused by the twists or indirect violence (Figs. 24 and 25). In children, incomplete fractures involving only part of the cortex, and green stick fractures may be encountered. The commonest site at all ages is the middle third of the diaphysis. Treatment aims to restore length by approximating the ends of the fragments, and

to maintain a normal limb axis in both a horizontal and longitudinal plane. Every effort is made to bring the limb's long axis into the proper line for weight-bearing, a straight line from anterior iliac spine through the middle of the patella and on to the second toe. The horizontal axial relation of fragments must also be normal. When

Fig. 24.—Transverse shaft fracture. Very difficult to reduce for end-to-end apposition and axial alinement.

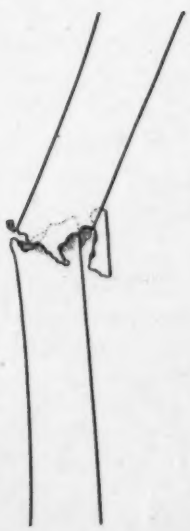

Fig. 25.—Transverse shaft fracture with interlocked fragments—not difficult to reduce.

these axes are not restored, the patient later develops static troubles in the neighboring joints, especially in the knee, and axial rotation may bring on foot troubles when walking is undertaken. Secondary axial deviations from too early weight-bearing on soft callus may cause these troubles.

Shortening is a result of shaft fracture that is most difficult to overcome. In transverse fracture, it sometimes becomes impossible by manipulation and extension methods to get the ends into contact—shortening as such may be overcome. Consequently, oblique and even long spiral fractures may offer a better prognosis, for reduction may be more easily accomplished and the length of the extremity more nearly restored. If the patient is placed on a fracture table an exact end-to-end contact is seldom obtained, even when considerable traction is applied. In oblique and spiral fractures also after the application of body casts following fracture table reduction, the spastic thigh muscles tend to cause a renewal of the displacement no matter how perfect it may have been as shown by roentgenogram at the time of reduction. The position of a shaft fracture, viewed by roentgenogram shortly after reduction and which may seem satisfactory, very frequently shows the original displacement when examined by the roentgen ray ten days later. When the fragment ends of a transverse fracture interlock by their serrated edges, a bowing is liable to develop later from muscle action within a heavy cast. Oblique and spiral fractures simply tend to slip back into the old displacement. It is practically impossible to maintain any real extension in the longitudinal axis of the leg by means of a plaster-of-Paris body cast.

With no hesitation, therefore, I can advise that there is no treatment comparable to continuous traction, best continuous suspension traction. The use of plaster casts for fractures of the shaft, except in instances of children or adults when there is green stick or incomplete fracture and little displacement, should be discarded. The best results in fractures of the shaft in children are obtained by suspension traction treatment. This I have demonstrated in a year's work on sixty-seven shaft fractures which were studied from the standpoint of methods and results of treatment. The extension used was gauze applied with Sinclair's glue to the unshaven limb, attached to a Thomas splint (Figs. 26 and 27). The splint was slung in suspension traction. Children have little trouble with limitation of joint motion after splint traction. Below the age of 4 years, on account of the disproportionate weight of the leg and the body, vertical extension, as usually employed, is advised.

It is not true on the other hand that continuous traction results in an anatomic reduction in all cases, but it assures the restoration of the weight-bearing axis of the leg, an insignificant shortening and a result approaching the normal. Depending on the site of the fracture and the displacement, we can use straight-in-a-line exten-

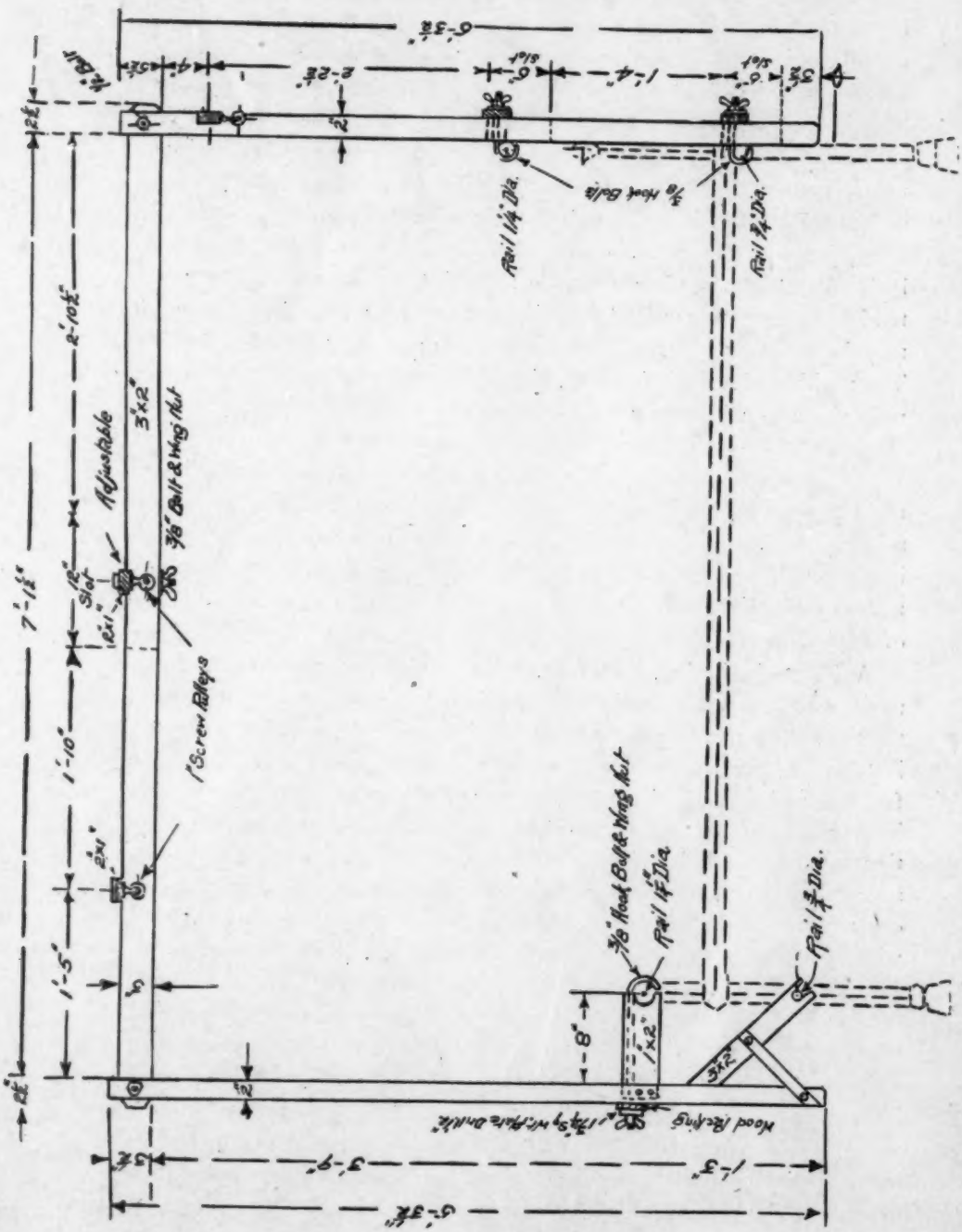

Fig. 26.—Side elevation of Balkan frame designed to fit standard 6 foot, 6 inch cot, in the construction of which four 7 pound sand bags and 12 yards of blind cord are required. Scale, 1 inch equals 1 foot.

Fig. 26.—Side elevation of Balkan frame designed to fit standard 6 foot, 6 inch cot, in the construction of which four 7 pound sand bags and 12 yards of blind cord are required. Scale, 1 inch equals 1 foot.

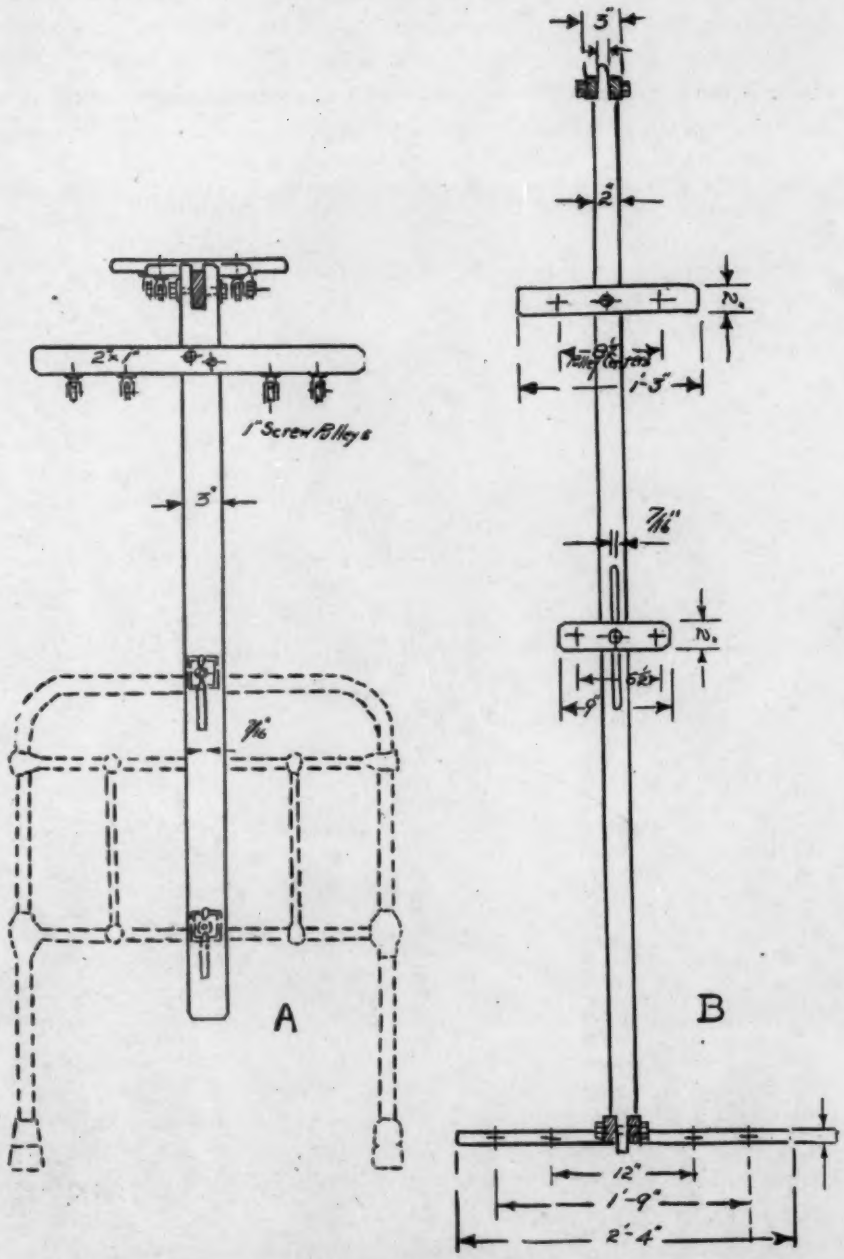

Fig. 27.—*A*, end view of Balkan frame; *B*, overhead frame.

sion or the splint can be bent to give semiflexion. Suspension traction is the best method of all as it allows these variations and furnishes one apparatus for the care of all shaft fractures. The rule already expressed concerning traction must be referred to (Fig. 28). Because the extension acts on the lower fragment and does not modify the axial direction of the upper fragment, it is necessary to bring

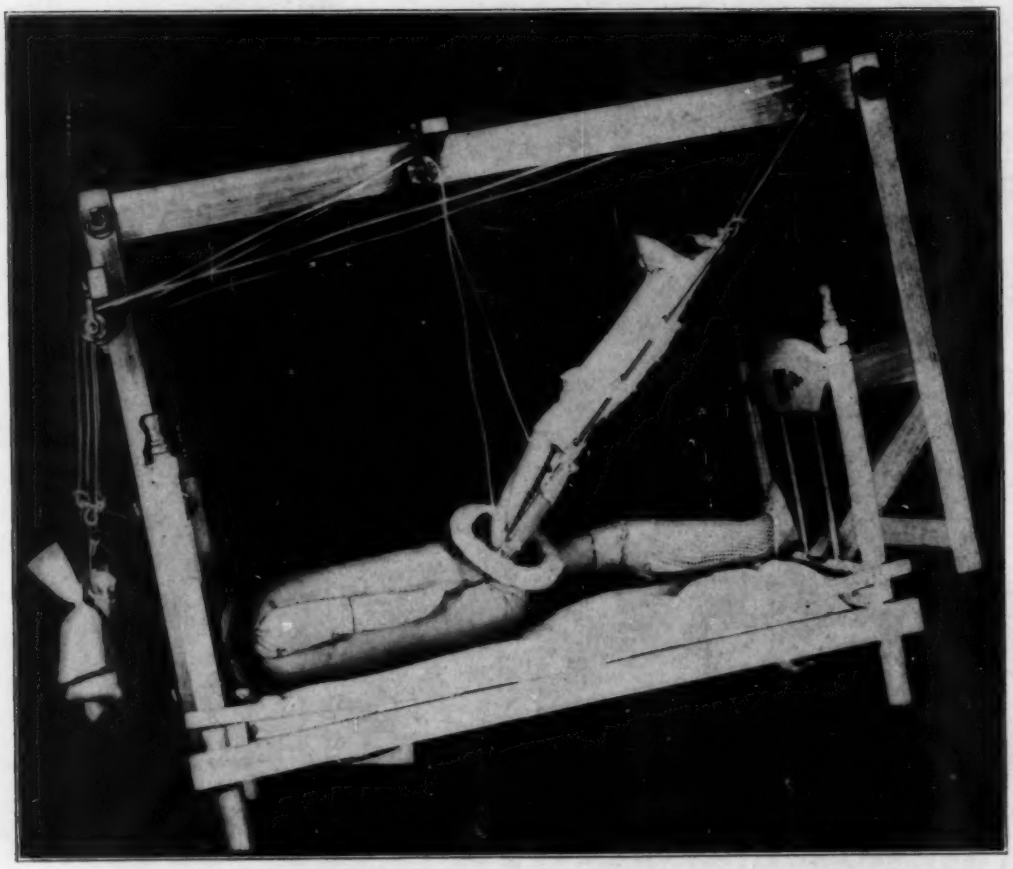

Fig. 28.—Model frame attached to doll's bed, the foot of which is elevated. The weights at the head of the bed are out of the way. The frame is compact and does not touch the floor, leaving the bed free to be moved about if desired.

the mobile lower fragment, which can be easily controlled, into line with the upper fragment.

Suspension traction of the limb in either a Hodgen or Thomas splint, the very best method of obtaining continuous traction, has not been in wide use. Sporadic attempts to revive the use of the Hodgen splint have been made and yet the method has not been widely adopted. This I believe

has been because the average American surgeon is not mechanically inclined. He favors plaster-of-Paris casts or some splint application which is put on once and taken off once before the patient is discharged. Any extension apparatus which involves daily attention and adjustment is too irksome to use. In rural districts, with the patient in his own home, a suspension traction method was deemed impractical because the surgeon could not see the patient often enough (Fig. 29). Among hospital patients, too much time was necessary for the attention required to adjust the splints; the nursing staff did not care to have wards

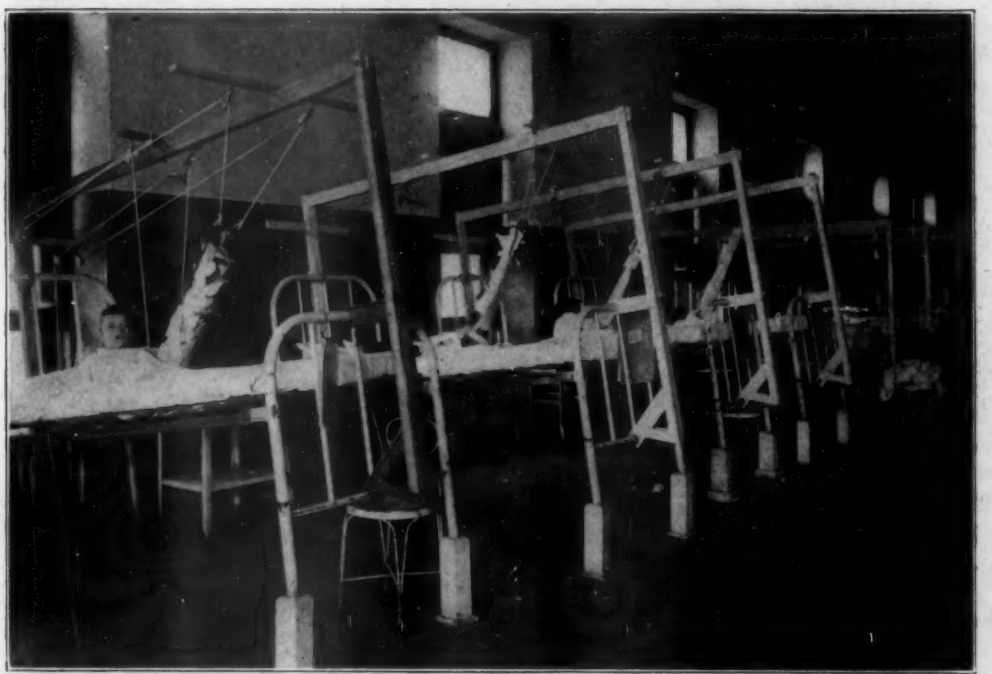

Fig. 29.—Overhead frames in actual operation. The nearest patient is sitting up to watch proceedings, without affecting the traction on his leg.

and beds disfigured by strange wooden frames. However, a certain proportion of active American physicians had an opportunity during the war to study the methods of suspension traction used by the French and English; this nucleus may help spread the use of the system (Fig. 30).

It is really a blow to American surgery that the idea of suspension traction so highly perfected by Hodgen should have fallen into the discard until revived by foreigners in the Balkan war and later in the World War. We now learn from them its great advantages and we wit-

ness its acceptance by the highest authorities as *the* means of treatment for shaft fractures. Too much is written at this time in the American literature about the use in foreign lands of the Thomas or other leg

Fig. 30.—Suspension traction for an adult. The splint is tied to the post, the extension on the leg is tied to the splint, so that the traction comes from the adult's body-weight.

splint for suspension traction of the thigh. If the writers would consult our own literature and would give credit to the Hodgen splint, America might come into some of the credit due the real inventor (Fig. 31).

MASSAGE AND ELECTRICAL STIMULATION

No résumé of the present treatment of femoral fractures can be complete unless attention is drawn to the extreme negligence shown by American surgeons in the way of providing accessory massage and electrical stimulation of muscles. These two adjuvants must, when possible, be applied during the course of repair. When the limb is enveloped in a plaster cast, they cannot be employed, another

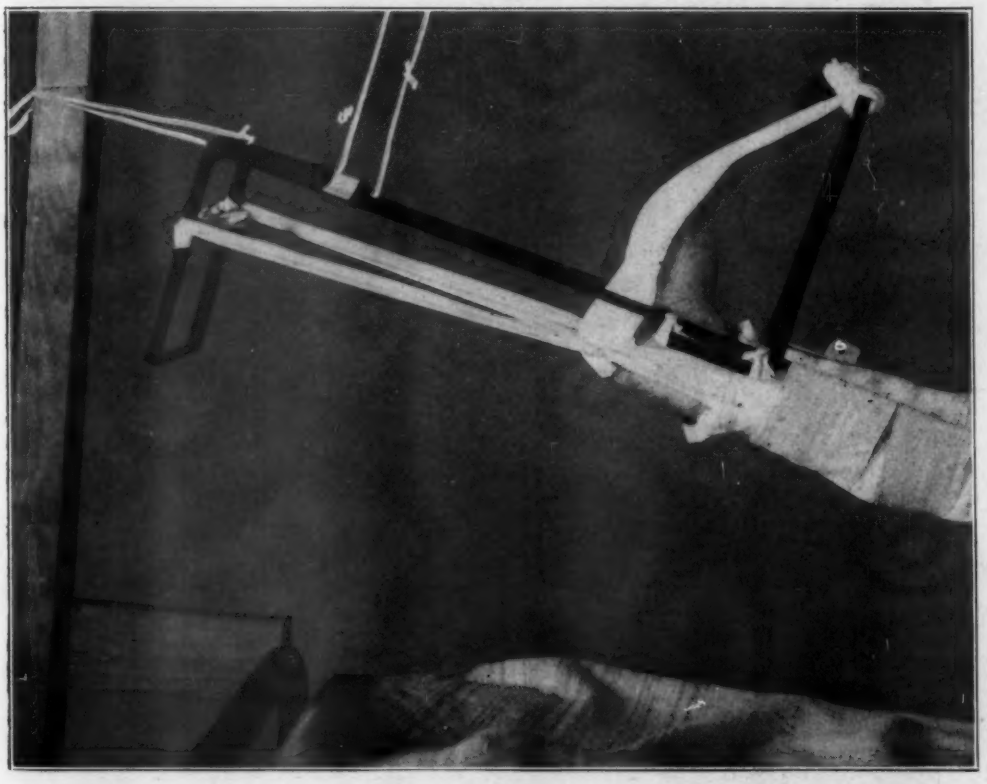

Fig. 31.—The foot is held up by gauze and glue, so that foot-drop cannot occur.

argument in favor of open dressing in suspension traction. The daily massage and galvanic stimulation of thigh muscles in fracture of the femur, whether open or closed, operated on or not, should be as much a part of routine ward work as making the patient's bed. It is rather disheartening to see the great amount of care bestowed on patients about to be operated on in hospitals as compared to the trouble taken in caring for fractured thighs. For the operative patient, all the resources of the hospital are called into play: special anesthetist, a

large operating room force, the surgeon and his assistants, everything being subordinated to the operation, and later much attention given to the postoperative care. The mortality among operative patients is no higher than among those suffering from fractures of the femur. The average patient after appendectomy is up and walking in eight or ten days—the average patient with a fracture of the femur has months of

Fig. 32. — Portable roentgen-ray machine, the operator making a bedside exposure without interfering with the suspension traction.

waiting before he can walk and then must often carry through life distinct evidence of his mishap. The relative economic loss of two such conditions cannot be compared.

As a result of massage and electrical treatment during healing of the bone, when the patient's splint is removed, the thigh and calf muscles are found prepared to function. There is no atrophy of disuse,

no waiting for shrunken thighs to regain size and power, and there is more rapid convalescence, free from fear of falls on account of loss of muscular power. Ambulatory calipers supplement this shortening of disability and insure a stability of the callus while reduction is maintained.

Fractures of the femur are very grave injuries; the supplies needed for caring for these patients, including frames, splints, extensions and dressings, should be as liberally and punctually supplied as those for laparotomy. The facilities for roentgenographic work for bedside diagnosis should be found in every hospital in which these fractures are treated (Fig. 32).

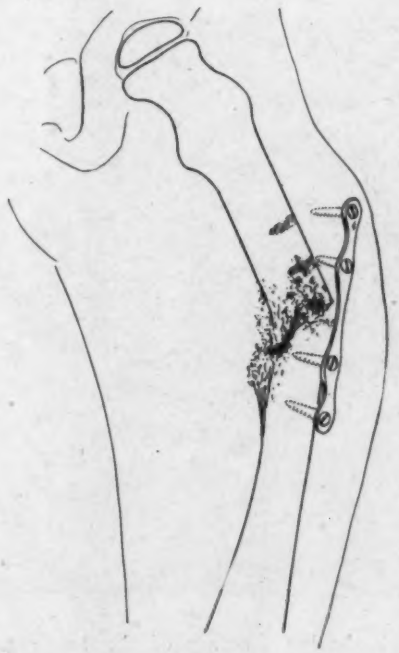

Fig. 33.—Shaft fracture in a child treated by Lane plate which has pulled out because of insufficient external splintage and too early weight-bearing.

AFTER-TREATMENT

When the callus has formed and can be felt to be firm by the examining hand (in children after three or four weeks; in adults after eight or ten weeks), the leg is lowered and kept loosely bound in a Thomas splint. The patient remains in bed and the splint protects the soft callus. After another week, a walking caliper having been made in the interim, the patient is fitted with a caliper and allowed to stand with crutches. The patient soon begins to walk, but the wise surgeon will see that the walking caliper fits perfectly and is worn for

from four to six months, depending on the type of fracture and the patient's bony reaction. With that security, one knows there will be no disappointments resulting from secondary deformities and shortening (Figs. 33, 34, 35 and 36).

Nail and Caliper Extension in Suspension Traction.—When ordinary traction fails, on account of damaged skin or slipping adhesive or glue, calipers or nail extension can be substituted. Should these fail to bring apial correction and full lengthening, as so frequently happens when the treatment is delayed too long, open operation offers a chance for anatomic reposition. By persistence and attention to

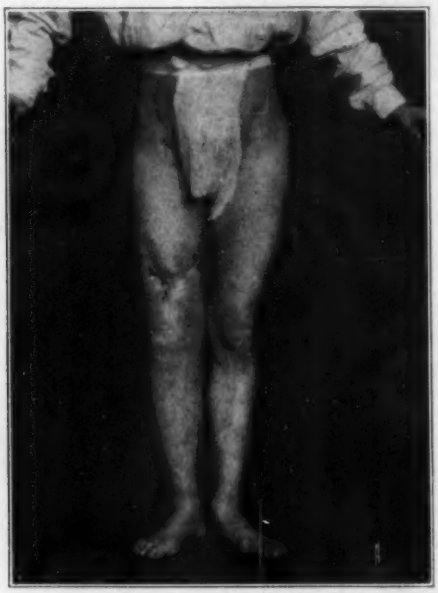

Fig. 34.—A healed gunshot fracture of the femur treated by suspension traction, showing the length obtained.

details, with inspection of leg, splints, ropes, pulleys and weights twice a day, the percentage of patients requiring nail or caliper extension will not rise over 3. We prefer the nail extension through the femoral condyles, and we employ steel drill rod sharpened at one end like a meat skewer, driven rapidly through the bone at the correct right-angled axis under the restrictions laid down by Steinmann. The nail will not slip as the caliper is inclined to, nor can the patient pull it out. The newer calipers like Schiassi's (Fig. 37) hold quite firmly; but any caliper is objectionable, inasmuch as there is some movement of the points within the skin wounds. This movement leads to a little

irritation and to infection which may not be serious, but which adds to the patient's troubles. The nail, on the other hand, does not move; it holds the lower fragment rigidly and permits a nice correction of the deformity. The nail also is cheap. We have had no infections from nails. In adults the nail treatment of femoral fracture must sometimes be used through the os calcis; in children this cannot be done on account of the slow development of this bone. A child up to 12 years of age has very little bone in the os calcis.

Portable Roentgen-Ray Control.—Regardless of the method used to obtain the traction in this suspension treatment, the operator must not trust alone to his eye for complete correction of the deformities. Roentgenographic controls by means of the portable roentgen-ray tube are absolutely necessary. If the patient's limb is removed from traction, and he is carted to a roentgen-ray room for exposure, the true

Fig. 35.—After the fracture has healed, attention is first paid to moving the knee joint while the patient is still confined to bed. The first step is bending the joint over a pillow.

state of reduction as obtained in the traction is lost. Consequently, the plates must be made while the limb is under traction with the patient in bed. When fractures of the shaft of the femur occur, they should be given immediate treatment. If that treatment is suspension traction, the roentgenogram for control must be made in case of a child within forty-eight hours, in case of an adult within four days, so that measures may be taken to vary the weight used in traction, to bend the splint at the proper angle, or to make pressure against one side of the limb or the other to correct axial deviations. There is no other way to insure a maximum correction of length and axis. It may happen that too much weight has been employed and that the fragments are actually separated.

SURGICAL TREATMENT

There are many methods of procedure in open operations. Usually the patient lies on the fracture table with the feet bound to the supports, ready for immediate application of a plaster-of-Paris body cast after the operation is finished and while the anesthesia is still effective. The simplest method of open operation is replacement of the fractured ends to the normal axis after correction of overriding and the local pathologic condition. Lane plates of steel, Parham's steel bands and wire are

Fig. 36.—The second step to increase knee joint motion. The patient is his own masseur.

used to hold fragments in position. Ivory or bone plates, with screws of corresponding material are also used. Inlay and intramedullary bone and ivory pegs are used, every internal operation requiring external splinting subsequently, a fact sometimes overlooked by the surgeon. Bone splints may be autogenous, taken from the tibia, fibula, or the femur itself, near the site of fracture. They may also be exogenous, usually beef bone used in the intramedullary fixations when a simple mechanical connection is desired. Numerous modifications of inlay bone fixations are offered, some sliding in character, taken from the

operative field, some held by bone dowels cut from their own substance, others held by flanged edges made in the sawing. For these operations there is required a special electric outfit. One may well conclude that the best operation is the one which obtains, by the simplest technic, a satisfactory end-to-end approximation which will hold with the aid of external immobilization. The longer the exposure and the greater the local manipulation of bone ends and implanted fragments, the greater the possibility of infection.

A Lane plate should be employed only when the fracture cannot be reduced and maintained in reduction by other means. In children the indication for its use is found in neglected fractures

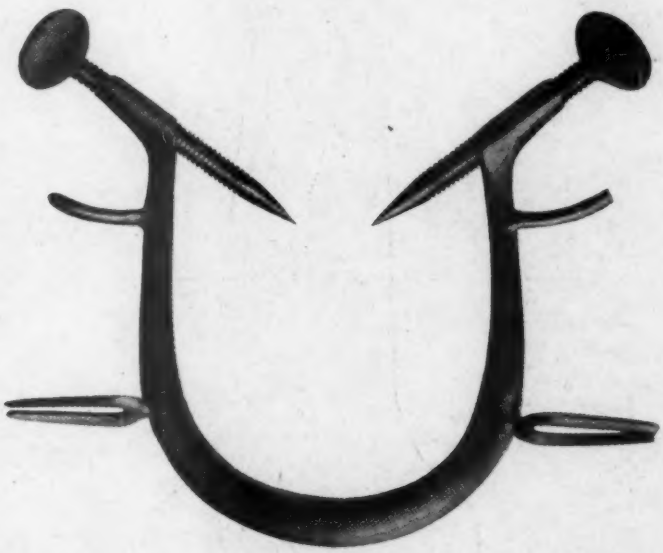

Fig. 37.—Schiassi's (Bologna) caliper for extension on the calcaneus. This can be modified for use above the malleoli or on the femur itself.

with overriding of from 2 to 3 inches, the fracture being of the transverse or sharp oblique type. When these fractures have not been submitted to suspension traction soon after their occurrence, the shortening soon passes beyond the possibility of being overcome by any traction, and callus forms so rapidly that within from two to three weeks a union is inaugurated. Therefore the ends must be freed, the callus removed, and the steadying plate is applied outside the periosteum. But we remove all such plates within six weeks in children and twelve weeks in adults; then we apply the walking caliper to protect the callus. The patient thus leaves the care of his surgeon with the plate removed: there are no complications. We believe that

the internal splint, especially one of nonabsorbable material such as a steel plate, is merely a means to an end. Its function is to hold the fragments in apposition until the bone wound is sealed by callus. Once that duty is performed, the metal plate should be removed; if that duty has not ended in a normal union in the customary period of time, its

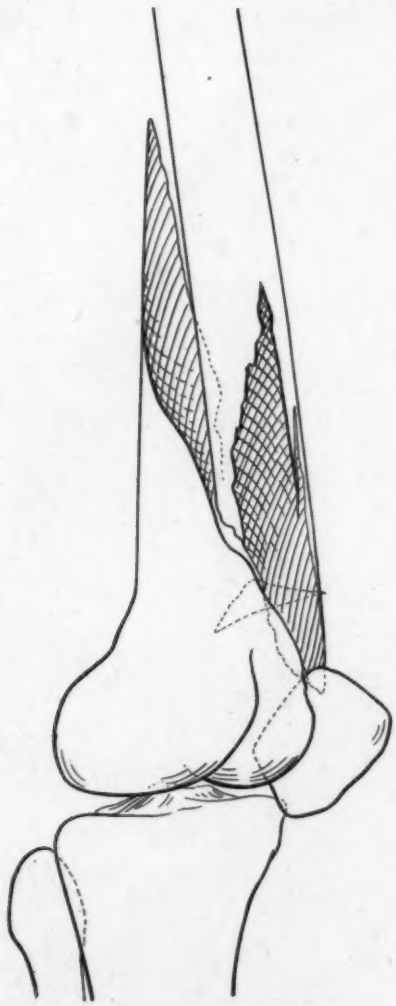

Fig. 38.—Spiral supracondylar fracture with penetration of the knee joint by the sharp upper fragment.

presence for any longer period is not likely to insure union. However, we may modify the time of removal a little in case callus development is slow, though the plate should be removed as promptly as possible.

SUPRACONDYLAR FRACTURES

These do not include separations of the lower epiphysis of the femur, nor true articular fractures. The supracondyloid site is that point of union between the diaphysis and its spreading portion that quickly widens into the massive condylar area. In children, fractures in this area are high up and may be green stick in character or even subperiosteal, but in adults we find the usual transverse or oblique and spiral types.

Fig. 39.—Unreduced bicondylar fracture which operation alone will benefit.

The primary displacement is usually due to a continuation of the force producing the fracture. The upper long fragment may be sharp, may penetrate muscles outward or inward or may be forced downward, lying just beneath the skin, or may penetrate the subcrural pouch of the knee joint to lie in contact with the patella (Fig. 38). The lower fragment is usually drawn backward and downward by the gastrocnemii. Injury of nerves and blood vessels may demand immediate treatment. A large hematoma should excite suspicion of vascular damage, and exploration need not be feared. Very early gangrene may call for amputation; but it is best delayed if possible for a line of demarcation.

Old Cases of Supracondylar Fracture.—Should a complete supracondylar fracture heal with shortening, vicious deformity and large callus, operation promises a functional result. Osteophytic outgrowths may greatly restrict knee joint motion or interfere with the vascular and nerve supply of the leg, and it is also common to find that there is restricted joint motion after the hemarthrosis which accompanies the fracture. The greatest part of the partial ankylosis of the knee probably comes from fibrous changes in the periarticular structures, less frequently from intra-articular fibrosis.

Treatment of Supracondylar Fracture.—The treatment of supracondylar fracture must be prompt (Fig. 39). When incomplete, or green stick, or only slightly displaced, extension on a fracture table with pressure of the fragments back into line, followed by a molded plaster

Fig. 40.—Epiphyseal separation with little displacement.

splint for four weeks, will give good results. It may be necessary to put the leg in flexion. If the hemarthrosis is large, the joint can be aspirated, but not until active hemorrhage has ceased.

When there is real displacement of fragments, extension manually or on a fracture table may assist in an easy reduction when pressure is made on the lower fragment. One must take pains not to injure the popliteal vessels. It is too frequently discovered, however, that after a reduction of this kind—especially in oblique and spiral fractures—the fragments immediately slip out of place, once the traction is released. Consequently, continuous traction must often be resorted to. The best position is with the thigh at right angles to the pelvis and the leg at right angles to the thigh, to relax the gastrocnemii. The extension is applied to the leg and the thigh, and the body acting as

a counter weight insures reduction. Nail or caliper extension applied to the lower fragment has a real use in these fractures. We can use here the double inclined plane; but we must be sure there is sufficient traction on the leg. If reduction does not follow within five days, open operation should be undertaken. When the thigh is opened (as it would be at first for all nervous or vascular lesions) the faces of

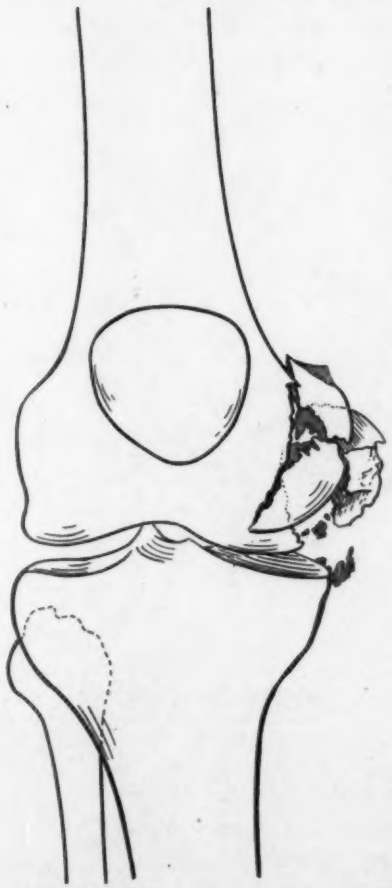

Fig. 41.—Fracture of internal condyle from direct violence.

the fragments may hold when reduction is accomplished. If the fracture is oblique or spiral, it may be held by a cerclage of wire, a Parham's band or an ivory or bone screw. The leg is held in flexion in a molded plaster-of-Paris splint. After three weeks, passive knee motion must be cautiously begun.

Separation of the Lower Epiphysis.—Separation of the lower epiphysis may occur in any direction, forward, backward, inward or outward. The ligaments of the knee joint usually remain intact and the distal

fragment retains its normal relationship to the tibia. In these accidents, vasculonervous complications must be searched for; also the stretching or tearing of the skin must be considered. In the treatment an examination for vascular and nervous lesions must first be made. When such are found, immediate operation is indicated (Fig. 40).

Treatment of Epiphyseal Separations.—For incomplete separations of the epiphysis, manual reduction must be performed at once under anesthesia. A plaster-of-Paris molded splint with the leg in extension will suffice for after-treatment. One great difficulty is the hematoma

Fig. 42.—Condylar fracture with displacement.

about the fracture. It spreads from groin to heel. There may develop a tendency to leg flexion after the patient becomes ambulatory—best guarded against by having him wear a walking caliper for three months. Complete displacements in any direction must be immediately reduced. Under anesthesia, usually ether, the knee is flexed acutely, an assistant makes counter traction on the flexed thigh and the surgeon, by traction on the flexed leg, pulls the epiphysis into position. The reduction is usually recognized by the soft cartilaginous rub as the surfaces pass into position.

After reduction, the leg and thigh are immobilized in a plaster-of-Paris gutter which holds the heel against the buttock. Two weeks in that position are sufficient. This position has the advantage of relaxing the hamstrings, of using the tension of the quadriceps as a splint and of preventing the contracting epiphyseal surfaces from lateral dis-

placement, much as the position of flexion of the forearm is used in elbow fractures.

Operative Treatment of Epiphyseal Separation.—If manipulation with extension fails to reduce the fracture, an open operation is necessary. The epiphyseal surfaces should not be roughly handled, likewise the diaphysis should never be shortened for fear of interfering with subsequent growth. If the fracture has healed in malposition, all callus must be removed, the fragment ends must be freshened gently and then completely reduced.

Fig. 43.—Replacement of condylar fracture shown in Figure 42 by means of traction and manipulation.

KNEE JOINT FRACTURES

Bicondylar fractures, T and Y fractures, are best treated by strong continuous extension in semiflexion. Manual pressure on the fragments can aid a reduction (Fig. 41). When this fails, an open operation must follow, best performed within eight days. These are true articular fractures and the operation is an arthrotomy. Two methods of approach are offered: The best is to saw the patella longitudinally, retract the extensor mass over the femoral condyles, bring them together, maintaining contact by an ivory screw or nail driven in laterally. The joint is then carefully and completely closed. Another method of approach is obtained by a large U-shaped incision extending just below the tibial tubercle, so that the insertion of the patellar tendon can be chiseled free and the joint exposed (Figs. 42 and 43).

FRACTURE RECORD

General Results:	GOOD	MODERATE	BAD
Anatomical			
Functional			

AMERICAN SURGICAL ASSOCIATION

1. Bone ..... 2. Site—Neck....Upper....Middle....Lower 3d....Condyle....Involving joint.....
.....
3. Name ..... 4. Sex—M.....F..... 5. Age..... 6. Occupation.....
7. Time fracture occurred—Date.....Hour..... 8. Hospital entered—Date.....Hour.....
9. First treatment—Date.....Hour..... 10. Cause of fracture.....
11. Kind of fracture—Oblique....Transverse....Spiral...Impacted....Comminuted.....Simple.....Compound....Greenstick....Subperiosteal .....
12. Was there serious injury to soft parts—Skin—Yes...No... Muscles—Yes....No... Vessels—Yes....No... Nerves—Yes....No...
13. Reduction: How many hours elapsed after accident before reduction? .....
14. Was anatomical reposition of fragments obtained? Yes....No.....
15. Anesthetic used: Yes....No.... Ether..... Gas.....
16. Fixation: Closed Method.
Postion: Hyperflexion.....full supination .....abduction.....
Splints .....
Plaster of Paris .....
Traction: Buck's....Thomas....Hodgen...Balkan frame...
Steinmann .....
Amount of weight used .....
17. Fixation: Open Method.
Was non-operative treatment tried first.....
How long after injury was operation performed.....
Was open reduction alone performed.....
What form of internal fixation used—Steel Plates....Wire....
Nails...Screws...Bone transplants or implants.....
Was it later necessary to remove fixation materials? Yes.....
No.... Date.....
18. Shortening at first examination.....cm. When all apparatus removed.....cm. Date.....
When discharged from hospital.....cm. Date..... At last observation.....cm. Date.....
19. X-Ray used—Yes...No...First finding—Date.....day before reduction; .....day after reduction

Plate No.	Fragments Displaced	Not	Slightly	Markedly	Over-riding	Rotation	Angulation
	Before reduction, date						
	After reduction, date						
	After union, date						

20. How long confined in bed..... ....How long in Hospital..... ....
21. How long did patient use crutches..... ....Cane .....
22. Results: Final examinations made..... weeks..... .months after injury. Union. Bony.....Fibrous.....Non-union.....
23. Disability: Absent....Partial....Complete....Estimated by..... ... ..Shortening. .Angulation....Swelling of soft parts....Pain ... Nerve involvement....Interference with joint function....Endurance ....
24. Mortality: Main cause of death....Age of patient....Shock. .Hemorrhage....Other injuries....Sepsis....Exhaustion .....
25. Duration of absence from work.....weeks. ... ...months .. ..
26. Is patient fully able to take his former job. . . . .
27. Present wage-earning capacity compared with former..... ... .
28. Compensation under insurance, legislative act or legal process obtained—Yes.....No..... Expected—Yes.....No.....

Fig. 44.—Fracture record sheet compiled by the American Surgical Association.

Fracture of a Condyle.—For condylar fractures, the best treatment is continuous extension in a straight line aided by manual pressure. Some prefer semiflexion, but it has failed in our hands. When reduction cannot be obtained, an operation should be undertaken to restore the articular surface of the knee.

CONCLUSIONS

1. Because there is no accepted American standard of results after fracture of the femur, there is no American standard of treatment.

2. A large percentage of the fractured femurs are cared for by the first physician that sees them; specialists are not employed to direct treatment.

3. There is not sufficient effort put forth to use abduction or suspension traction methods, as obtained by the Hodgen or Thomas splint in fractures of the shaft, which may allow knee motion during the course of bone repair without disturbing the extension.

4. Portable roentgen-ray outfits should be furnished in all hospitals treating fractures of the femur, so that results in the course of treatment can be checked as frequently as desired.

5. There have been too many operations performed on fractured femurs by inexperienced operators, and without proper indication.

6. Very little attention is given to massage and electrical stimulation of muscles during bone repair and still less is given to after-treatment, so that many patients are permitted to bear weight on soft callus. Disability results. Walking calipers are little used.

7. The remedies suggested are:

(a) Every patient with fracture of the femur should be directed to a hospital for roentgen-ray examination, correct treatment by any of the accepted methods, and after-treatment when cured. This includes fitting the patient with a walking caliper as soon as he is ambulatory or on his discharge from the hospital.

(b) Because fracture tables offer good means of securing reduction and an easy method of external splinting by plaster of Paris, every hospital receiving cases of fracture of the femur should possess a fracture or orthopedic table. Careful records should be kept in accordance with a fracture record sheet (Fig. 44) such as has been compiled by the American Surgical Association, so that a large number of average results can be grouped, that treatment looking toward the ideal may be worked out.

THE ASSOCIATION OF HEPATITIS WITH EXPERIMENTAL CHOLECYSTITIS AND ITS BEARING ON THE PATHOGENESIS OF CHOLECYSTITIS IN THE HUMAN *

M. G. PETERMAN, M.D.; WALTER S. PRIEST, JR., M.D.,
AND
EVARTS A. GRAHAM, M.D.
ST. LOUIS

A review of the literature on infections of the biliary tract reveals the fact that there is a wide difference of opinion as regards both the frequency and the nature of an hepatic involvement in association with the relatively simple and more common types of cholecystitis. Such conditions as liver abscess and "obstructive biliary cirrhosis" in association with infections of the biliary tract have long been known. But the changes in the liver which occur in connection with the relatively simple types of cholecystitis which are so commonly encountered at operation seem not to have been investigated until the study made by one of us (Graham), the results of which were published in 1918.[1] In general, the only evidence of hepatic involvement which has been considered has been an increase in the size of the liver. Kehr [2] quotes Langenbach as saying that an enlargement of the liver is present only with an obstruction of the common duct. Kehr himself considers that the liver may be increased in size in from 15 to 20 per cent. of cases of cholecystitis, namely, in those with cholangitis. There is a more general agreement, however, about the involvement of the liver in cases in which calculi are present, in other words, in cases of long-standing inflammation of the biliary tract. Thus Grube and Graff [3] state that not uncommonly an interstitial hepatitis which may advance to cirrhosis is found associated with gallstones. Naunyn [4] quotes Charcot as being the first to call attention to the constancy of an enlargement of the liver in association with gallstones, and he considers that such an hyper-

* From the Department of Surgery, Washington University Medical School, St. Louis.

1. Graham, E. A.: Hepatitis: A Constant Accompaniment of Cholecystitis, Surg., Gynec. & Obst. **26**:521 (May) 1918.

2. Kehr: Chirurgie der Gallenwege, in Bruns: Neue Deutsche Chirurgie, 1913, p. 303.

3. Grube and Graff: Die Gallensteinkrankheit und ihre Behandlung, Jena, Gustav Fischer, 1912.

4. Naunyn: Klinik der Cholelithiasis, Leipzig, Vogel, 1892.

trophy is seldom absent during or shortly following an attack of gallstone colic. He considers the enlargement, under such circumstances, to be not exclusively due to a biliary obstruction, but also to an infective cholangitis. In 1888, Riedel [5] described the tongue-shaped extension of the right lobe of the liver now commonly known as "Riedel's lobe." He regarded this process as a result of disease of the biliary tract, and he asserted that he had found the liver involved in twenty-four out of forty-two cases of cholelithiasis. Quincke [6] remarks that in cases of cholelithiasis the liver is, as a rule, distinctly enlarged, due perhaps to a stasis of bile, or, in the case of women, to the effects of lacing. Rolleston [7] mentions an enlargement of the liver which may occur in association with cholecystitis if the inflammation has spread to the ducts and so into the organ. But evidently he does not consider this possibility as of very frequent occurrence.

It is the purpose of the present article to call attention to the great frequency of the involvement of the liver in different types of biliary tract infection and to present evidence in favor of the view that cholecystitis is probably often due to an infection by way of the lymphatics of the liver.

In a previous article by one of us (Graham),[1] a report was made of a study of the liver in various types of biliary tract disease, based on the examination of small pieces of liver which were removed during the course of operations on the gallbladder and bile ducts. In that article, it was stated that in thirty consecutive cases of biliary tract disease which had come to operation a distinct enlargement of the liver was present in twenty-six, or in 87 per cent. In the remaining four, there was definite gross evidence of a previous or existing pathologic change in the liver other than an enlargement. In cases of acute or subacute cholecystitis, there was constantly found in the liver microscopic evidence of inflammation. The hepatic inflammation was characterized by leukocytic infiltration of the interlobular, or periportal, sheaths; in the more severe types of inflammation, the infiltration involved also the parenchyma at the peripheries of the lobules and was associated with edema, slight necrosis and moderate fat infiltration. The inflammatory reaction was observed to be chiefly a pericholangitis. Although the intensity of the hepatic changes varied roughly in proportion to the intensity of the cholecystitis, nevertheless, definite inflam-

5. Riedel: Ueber den Zungenformigen Fortsatz des Leber lappens, Berl. klin. Wchnschr. **25**:577 and 622, 1888.

6. Quincke: Diseases of Liver, Pancreas and Suprarenal Glands, in Nothnagel: Encyclopedia of Practical Medicine, Philadelphia, W. B. Saunders Company, 1903, p. 381.

7. Rolleston, H. D.: Diseases of the Liver, Gall-Bladder and Bile-Ducts, London, MacMillan & Co., 1912, p. 611.

matory changes were found in the liver in cases of relatively mild cholecystitis (catarrhal) without calculi. In chronic cholecystitis, the liver often presented microscopically a picture practically identical with that of an early case of cirrhosis even when there had never been a stasis of bile. Cultures from both the liver tissue and from the bile in the gallbladder usually revealed the same organism.

It seems reasonable, therefore, to assume that an involvement of the liver is so frequently an accompaniment of cholecystitis that the

Fig. 1.—Distended lymphatic vessels of pig's gallbladder (taken from Sudler). This distribution is practically identical with that in man. The intimate communication between the lymphatics of the liver and gallbladder is well shown at the sides of the gallbladder.

association must be practically a constant one. The realization of this fact is important for several reasons: (1) because it may cause light to be thrown on the exact pathogenesis of infections of the biliary tract, which, if known, might serve both to prevent many cases and to settle disputed points in the treatment; (2) because it may prevent

many of the serious liver complications which seem to be largely a result of the neglect of early cases of cholecystitis, and (3) because it may lead to an increase of our knowledge of the whole subject of cirrhosis of the liver and various functional disturbances about which so little is known at present.

Present conceptions of the pathogenesis of infections of the gallbladder and bile tracts are based on three assumed possibilities: (1) descending infection from the liver by bacteria carried down in the bile, (2) ascending infections from the duodenum up the lumen of the common bile duct, and (3) hematogenous infections of the gallbladder and ducts.[8] Of these possibilities, it is only the last, the third, which takes into serious consideration the actual infection of the wall of the gallbladder, despite the fact that microscopic examinations of inflamed gallbladders demonstrate that inflammatory changes are present not merely in the mucosa but also in the deeper layers and that usually in gallbladders removed at operation, these changes are more pronounced in the deeper layers. The other two possibilities are concerned only with the entrance of organisms into the lumen of the gallbladder and do not explain their entrance into its walls. Obviously, the mere presence of pathogenic bacteria in the bile contained in a gallbladder does not constitute a cholecystitis; nor does it necessarily imply that a cholecystitis will occur through contact of the mucosa with these organisms. For example, according to Rolleston,[9] "in typhoid fever the bacilli are always present in the gallbladder but cholecystitis is comparatively infrequent." The essential requirement is that the wall of the gallbladder shall be infected since the gallbladder consists of nothing but a wall surrounding a cavity. Failure to take this simple fact into consideration has led to much confusion in the interpretation of experimental results on the pathogenesis of cholecystitis. Rosenow[10] has particularly emphasized the idea of the hematogenous infection of the wall of the gallbladder.

On the other hand, another source of infection, which is probably a frequent and an important one, is by way of the lymphatics from the liver. Strangely enough we have been unable to find in the literature any reference to the fact that this channel of infection has even been considered, although we have succeeded in collecting evidence

8. A fourth possibility of a spread of infection through the wall of the gallbladder from an inflamed contiguous organ has been mentioned; but obviously such an occurrence must be relatively rare.

9. Rolleston, H. D.: Diseases of the Liver, Gall-Bladder and Bile-Ducts, p. 608.

10. Rosenow, E. C.: The Etiology of Cholecystitis and Gallstones and Their Production by the Intravenous Injection of Bacteria, J. Infect. Dis. **19**:527 (Oct.) 1916.

which indicates that it must be a relatively frequent occurrence. Sudler,[11] in a careful study of the lymphatics of the gallbladder, has shown that there is a direct and intimate connection between the liver and gallbladder through lymphatics which come from the under surface of the liver and pass through the attachment of the gallbladder to the liver. The lymphatics of the gallbladder can be distended by injections into the portal vein. It is therefore easy to understand how organisms may spread through the lymphatics to the gallbladder wall from an

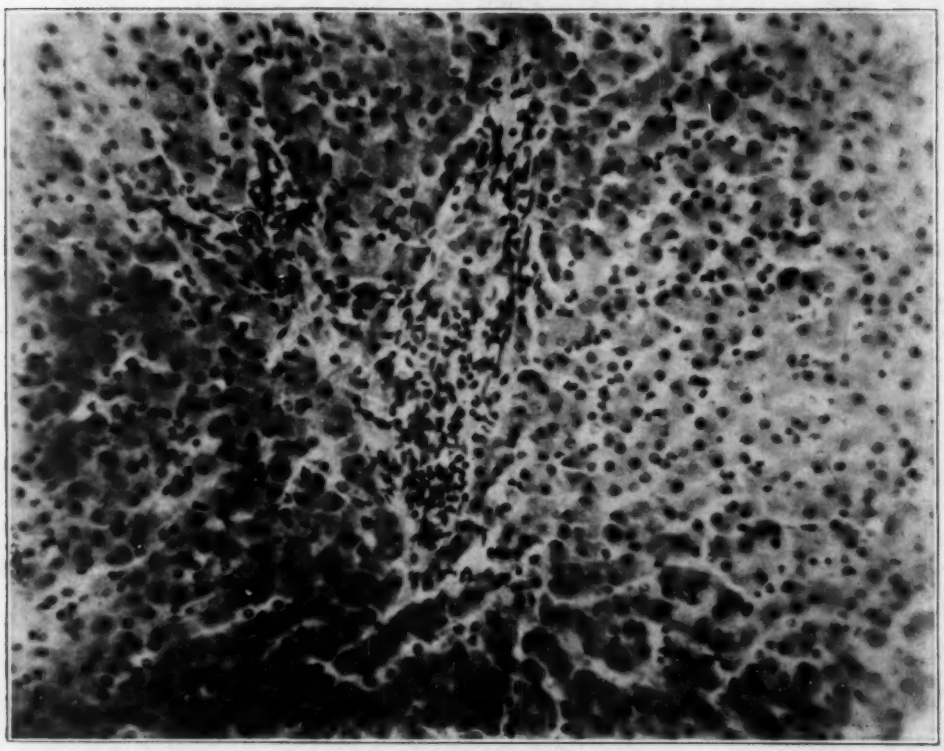

Fig. 2 (Dog 2).—Infiltration of periportal sheaths and parenchyma of liver with polymorphonuclears and round cells.

infection in the liver and thus set up a cholecystitis secondary to a hepatitis. In fact, it seems a much more probable mode of infection than the rather fanciful one of a surface infection of the mucosa of the gallbladder through contact with organisms, floating in the bile, which have been either washed down from the liver or have ascended from the duodenum against the current of the bile in the common and

11. Sudler: The Architecture of the Gall-Bladder, Bull. Johns Hopkins Hosp. **12**:126, 1901.

cystic ducts. In our experiments on dogs, we have found it practically impossible to produce cholecystitis merely by the introduction of organisms into the lumen of the normal gallbladder, even in thick suspensions. The additional factor of obstruction to the outflow of bile seems to be necessary to produce cholecystitis in this way. This also probably implies as a usual occurrence some degree of obstruction of the circulation of the gallbladder by pressure either from within or without. In this connection, the experiments of Chiarolanza [12] are of interest. After injections of typhoid bacilli both intravenously and subcutaneously in rabbits, he found that bacteria lodged in the papillary folds of the gallbladder beneath the mucosa in clumps which he interpreted as capillary emboli. In three animals in which the cystic duct was ligated before the injection, he found bacilli in the bile of the gallbladder. In six animals in which he ligated both the cystic and common ducts before the injection, he found bacilli in large numbers in the gallbladder bile. He concluded that cholecystitis is due to capillary embolism and not to infection from infected bile which is secreted. The livers frequently showed a more or less extensive interlobular leukocytic infiltration and often a marked increase of interlobular connective tissue, similar to what we have noted in the human liver in association with cholecystitis. In rabbits it is practically impossible to avoid the cystic artery in ligation of the cystic duct because of its small size, and Chiarolanza considered that in every case he had ligated the artery with the duct. It is hard, therefore, to understand his conception of the occurrence of capillary embolism in gallbladders the arterial supply of which was already occluded. It seems more probable that with both the artery and the duct ligated the organisms must have gained entrance to the gallbladder through the lymphatic connection with the liver, which has already been mentioned.

Of more practical interest are the questions of the frequency of liver involvement following a cholecystitis and the paths by which the infection is spread to the liver. The question of the advisability of the removal of an inflamed gallbladder is intimately related to the question of how frequently an infection of the liver may follow a cholecystitis. Because of the intimate lymphatic connection between the liver and gallbladder, it is easily conceivable that a vicious circle could be established with the liver on the one side and an infected gallbladder on the other, each being constantly reinfected from the other. Hence the desirability of ascertaining the frequency with which the liver is infected secondary to a cholecystitis is evident. Observations previ-

12. Chiarolanza: Experimentelle Untersuchungen über die Beziehungen der Typhusbazillen zu der Gallenblase und den Gallenwegen, Ztschr. f. Hyg. u. Infectionskrankh. **62**:12, 1909.

ously reported by one of us (Graham [1]), to which reference has already been made, indicate that the association of a hepatitis with a cholecystitis is nearly a constant one. But since in the clinical cases studied, the possibility existed of the hepatitis having been primary to the cholecystitis, it seemed desirable to submit the question to experimental study. Experiments accordingly were carried out which had as their object the study of the liver after the creation of a cholecystitis.

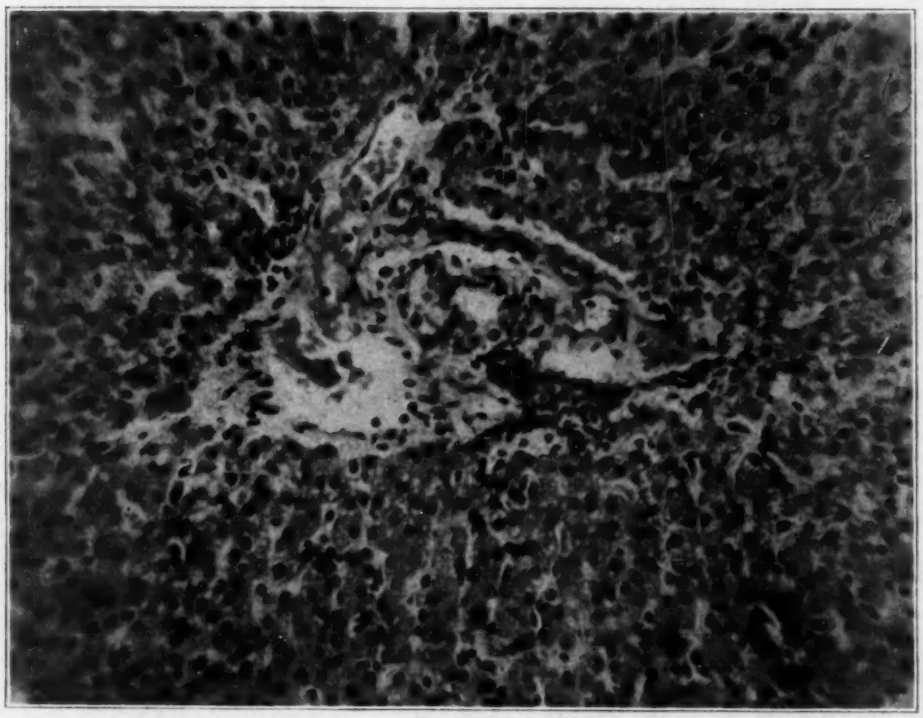

Fig. 3 (Dog 9).—Liver: interlobular leukocytic infiltration.

METHOD OF EXPERIMENTATION

In all, nineteen dogs were used. The following method was used as a routine. After noting the weight and rectal temperature, the animals were anesthetized with ether, and the abdomen was opened by means of an upper right rectus incision from 8 to 10 cm. long. A piece of liver was removed from the most accessible lobe to serve as a control for the later study of the liver after the production of the experimental cholecystitis, and the cut edges were sutured. Only those dogs are included in the series whose livers proved to be normal at the beginning. In some cases, stab cultures of the liver were taken at this time from as many different points as could be reached without

difficulty in order to test the sterility of the liver before the creation of the cholecystitis. In some of these instances, the surface of the liver through which the stab was made was seared in order to rule out possible contamination. Following this, the cystic duct was ligated. This included ligation of the cystic artery, vein and the lymphatic trunks which run along the cystic duct. In some cases, the duct and vessels were ligated twice and the structures divided between the ligatures. Before ligation, the gallbladder was almost completely emptied of bile. We then injected varying amounts (from 0.3 to 2.5 c.c.) of twenty-four hour broth cultures of pathogenic organisms (*B. coli* and *Streptococcus nonhemolyticus*) into the lumen of the gallbladder and closed the needle hole with a purse-string suture. It was found necessary to use a purse-string suture here to prevent leakage even after using the finest needle which could be employed. The abdomen was then closed in layers, and the dog was placed in the observation room. The temperature and general symptoms of each dog were followed daily. Whenever possible the dogs that died were immediately examined at necropsy. Several dogs were operated on a second time and some were killed and postmortem examination was promptly made. At necropsy sections of the gallbladder were taken in two places and of the liver in three places, namely, near the site of the gallbladder and from the extremes of the right and left lobes.

TABLE 1.—Agglutination Results with Injection of Bacillus Coli

Strain	Homologous Serum	Normal Serum
Dog 10:		
Gallbladder	Positive agglutination, 1:320	Positive agglutination, 1:20
Gallbladder	Positive agglutination, 1:320	Positive agglutination, 1:20
Liver, right lobe	Positive agglutination, 1:160	Positive agglutination, 1:20
Original strain injected	Positive agglutination, 1:320	Positive agglutination, 1:20
Stock strain	Positive agglutination, 1:20	Positive agglutination, 1:20
Stock strain	Positive agglutination, 1:20	Positive agglutination, 1:20
Dog 11:		
Gallbladder	Positive agglutination, 1:160	Positive agglutination, 1:20
Liver near gallbladder	Positive agglutination, 1:160	Positive agglutination, 1:20
Liver, right lobe	Positive agglutination, 1:160	Positive agglutination, 1:20
Intestine	Positive agglutination, 1:40	Positive agglutination, 1:20
Original	Positive agglutination, 1:160	Positive agglutination, 1:20
Stock	Positive agglutination. 1:20	Positive agglutination, 1:20
Stock	Positive agglutination. 1:20	Positive agglutination, 1:20
Dog 13:		
Gallbladder	Positive agglutination, 1:640	Positive agglutination, 1:20
Liver, left lobe	Positive agglutination, 1:320	Positive agglutination, 1:20
Liver	Positive agglutination, 1:320	Positive agglutination, 1:20
Intestine	Positive agglutination, 1:20	Positive agglutination, 1:20
Intestine	Positive agglutination, 1:40	Positive agglutination, 1:20
Original	Positive agglutination, 1:640	Positive agglutination, 1:20
Stock	Positive agglutination. 1:20	Positive agglutination, 1:20
Stock	Positive agglutination. 1:20	Positive agglutination, 1:20

In order to establish the fact that the inflammatory changes in the liver secondary to an experimental cholecystitis were actually the result of the gallbladder infection, it was necessary to show that the same

organism was present in both the gallbladder and liver. For the determination of this point it was considered advisable to submit to agglutination tests the organisms recovered from the gallbladder and liver, respectively. It seemed particularly important to carry out these tests in connection with the colon bacillus, since as is well known, this organism may sometimes be found in the normal liver. In the streptococcus cases, however, this procedure was not undertaken because it was believed unlikely that a streptococcus would be found as an accidental invader of the liver. Accordingly, therefore, after taking cultures at

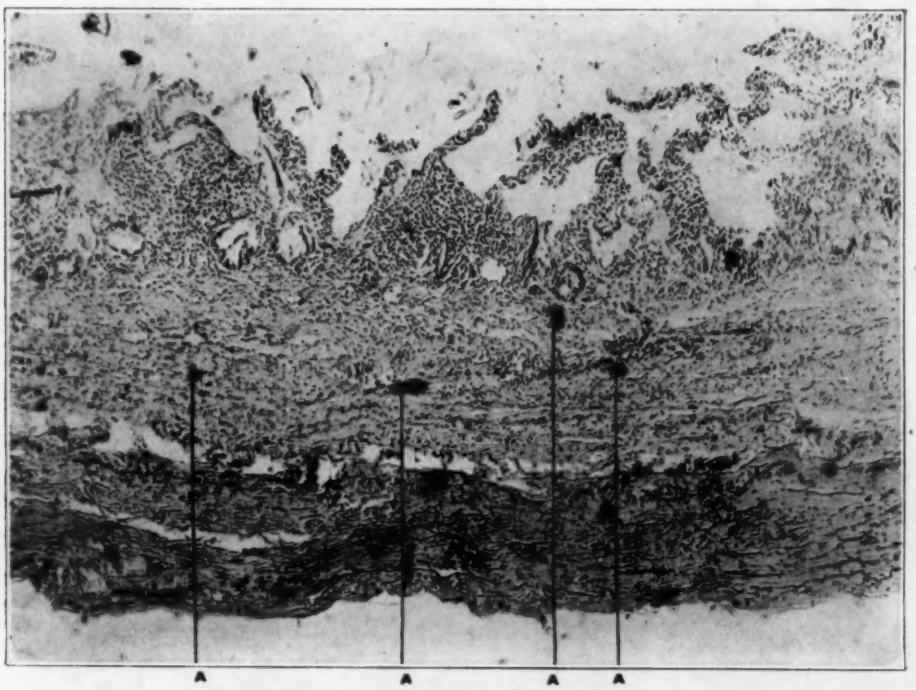

Fig. 4 (Dog 9).—Gallbladder, showing infiltration of leukocytes deep in the gallbladder wall. Each *A* indicates a clump of leukocytes.

necropsy from the gallbladder and from the liver in places corresponding to those from which sections were removed, a series of agglutination tests was run (Table 1) to prove the identity of the organisms recovered from the gallbladder and liver, respectively. In each of three cases it was proved by this method that the strains of *Bacillus coli* recovered from both gallbladder and liver were identical. As is shown in the table, the dog's serum agglutinated these two strains in much higher dilutions than other strains of colon bacilli taken from various sources including the intestine of the same dog. In most of the experiments, cultures were also made of the heart's blood. In isolating the various

strains used in making these agglutination tests, stabs were made at various parts of the liver and inoculated into melted nutrient agar which was then poured into plates. After incubation, colonies were picked and those showing morphology, staining and cultural characteristics of *B. coli* were cultivated in pure culture. Agglutination was carried out with uniform suspensions of eighteen to twenty-four hours' agar slant cultures washed off in physiologic sodium chlorid solution. The serum from the experimental dogs was obtained either just prior to killing them for pathologic study, or at the time of a secondary operation. All strains were agglutinated against serum from normal dogs as a control. Two strains were also obtained from stock laboratory cultures other than the one used in injecting the gallbladder and were used throughout the tests as a further control. These are designated as "stock" in the table. In two of the agglutination tests, strains were also obtained by isolating *Bacillus coli* from the intestine of the experimental animal. This was done to rule out the possibility that the strains recovered from the liver might be the same as those normally inhabiting the dog's intestinal canal. These strains are called "intestine." The failure of the homologous serum in high dilutions to agglutinate these strains, in addition to the other facts brought out, is, we believe, proof that the *Bacillus coli* isolated from the liver was the same as that injected into the gallbladder. The amounts of bacterial cultures injected in each experiment, the postoperative course, the necropsy findings and the histologic changes observed are given in detail in the protocols.

DISCUSSION

In all of these nineteen cases of experimental cholecystitis, inflammatory changes have been observed in the liver. These have consisted chiefly of a leukocytic infiltration around the bile ducts in the interlobular sheaths. The pathologic condition observed has been practically identical with that already noted by us in human cases of relatively acute infection; but the experiments were not continued long enough to observe any pronounced evidence of cirrhosis such as was seen in some of the chronic cases in human beings. The hepatitis in association with streptococcal cholecystitis was more severe than that which occurred in infections with *B. coli*. The fact that these changes are known not to have been present before the creation of the cholecystitis and that they have consistently followed it in each case makes apparent the probability that all cases of cholecystitis are accompanied by a hepatitis. This deduction agrees with the conclusion reached in a previous article by one of us (Graham) in which a report was made of a study of the liver based on an examination of small pieces of it removed at operations on the biliary tract. In our experiments recorded

here the cystic duct was ligated, and at the same time the large lymphatic trunks passing along that duct were obstructed by the ligature. The only paths, therefore, by which the infection could have spread to the liver were either the lymphatics or veins from the gallbladder which pass through the normal attachment of that organ to the under surface of the liver, or by way of a general blood stream infection back to the liver. Since in six of the

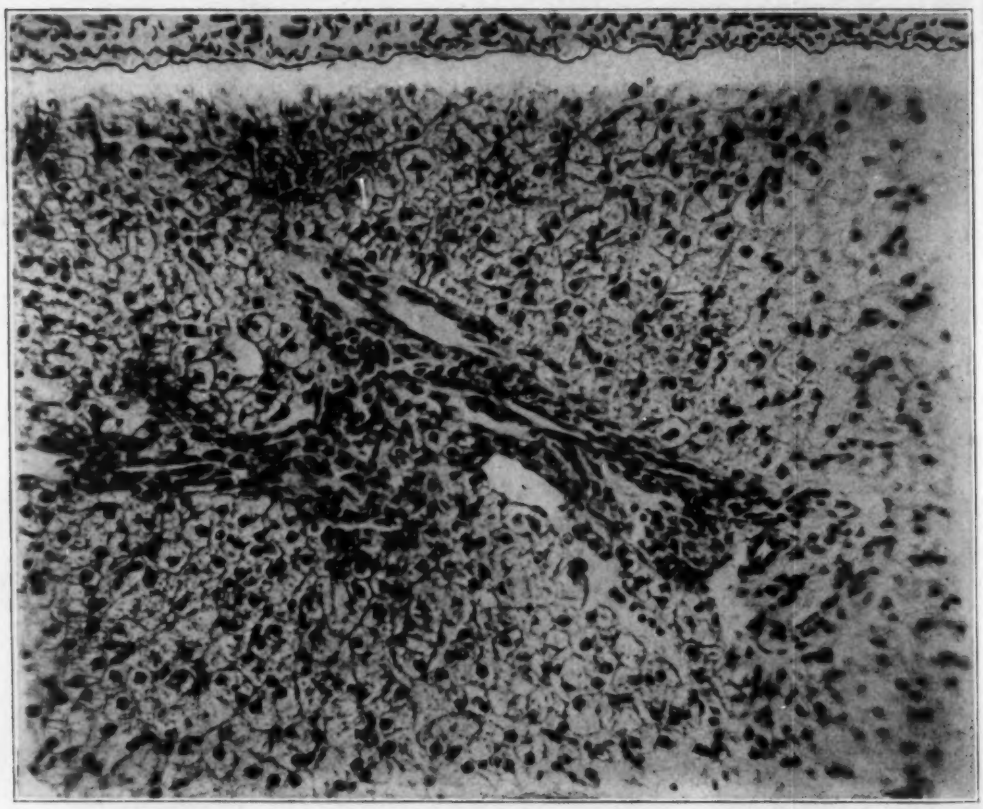

Fig. 5 (Dog 10).—Liver: moderate leukocytic infiltration of periportal space

cases, cultures from the heart's blood were sterile, it seems more probable that the infection spread directly to the under surface of the liver. The lymphatic connection here is well shown in Figure 1, taken from Sudler's article, and it would be easy to conceive of the extension of the infection into the liver by way of these lymphatics. Additional support to this view is found in the fact that the leukocytic infiltration is consistently more pronounced in portions of the liver near the site of the gallbladder than at more remote parts. This is seen, for example, in Figures 9 and 10. Since, on the other hand, the

veins in the attachment of the gallbladder to the liver drain into the portal vein (Sudler), one would expect that infection transported in this way would be nearly equally distributed throughout the liver. Moreover, the location of the inflammatory changes chiefly in the interlobular areas harmonizes with known facts about the location of the lymph vessels of the liver.[13] It would seem evident, therefore, that the abundant lymphatic connections between the liver and gallbladder already mentioned render the possibility of the frequent occurrence of a vicious circle between an inflamed gallbladder and an inflamed liver very great. In such circumstances, surgical intervention to break up the circle can be brought to bear only on the gallbladder; and, in fact, because of the well known ability of the liver to destroy bacteria, probably all that is necessary in most instances, is to remove the source of the infection, the gallbladder. In many respects, as, for example, in its shape and structure, the gallbladder resembles the appendix. Like the appendix, also, infections of its walls tend to become chronic, possibly because of its relatively slight vascularity and the ease with which its blood supply can be seriously impaired. Simple drainage of the gallbladder, therefore, cannot be expected to yield the same high percentages of permanent relief that its removal will accomplish, from the same standpoint that one would not expect to accomplish such good results with appendicostomy as with appendectomy. In this clinic, cholecystectomy is considered the operation of choice.[14]

SUMMARY

After the experimental production of cholecystitis in dogs, inflammatory changes have been constantly found in the liver. These changes have been of the same type as those previously described by one of us (Graham) as occurring constantly in the human liver in association with biliary tract infections, namely, a pericholangitis with marked leukocytic infiltration of the interlobular sheaths. The same organism can be isolated from both the liver and gallbladder.

Evidence is submitted that, owing to the free lymphatic communication between the liver and gallbladder, infection may pass easily from one organ to the other and a vicious circle be produced in this way.

Infections of the gallbladder apparently by way of the lymphatics from the liver are easily produced experimentally. In any considera-

13. Mall, F. P.: On the Origin of the Lymphatics in the Liver, Bull. Johns Hopkins Hosp. **12**:146, 1901.

14. The question of the rôle of drainage in assisting the liver to overcome its infection will be taken up in another article to be published soon.

tion of the pathogenesis of cholecystitis in the human, this lymphatic route must be regarded as important and probably frequent, although apparently it has heretofore received no attention.

The probability of a frequent occurrence of a vicious circle between an inflamed gallbladder and an inflamed liver would seem to afford a strong argument in favor of cholecystectomy as an operation of choice in cases of cholecystitis.

PROTOCOLS

Dog 1.—This experiment is the only one of the series in which the cystic duct was not ligated and in which a cholecystitis was produced without ligation of the duct. In several preliminary experiments it was found impossible to produce cholecystitis merely by the injection of bacteria into the lumen of the gallbladder if the cystic duct was not ligated. Two c.c. of *B. coli* culture was injected into the lumen and wall of the gallbladder. The dog did well except for slight elevation of temperature and poor appetite until the seventeenth day. It died on the twentieth day.

TABLE 2.—Condensation of Protocols

Dog	Organism Injected	Amount	Soiling	Days Lived	Postoperative Course†	Second Operation	Days Lived After Second Operation	Normal Liver Culture	Normal Liver Section	Peritonitis	Gross Changes	
											Gallbladder	Liver
1	B. coli	2.0	0	20	D	0	..	..	Neg.	0	Acute inflammation	None
2	B. coli	2.5	0	4	D	0	..	..	Neg.	+	Acute inflammation	Edema; congestion
3	B. coli	1.0	0	8	D	0	..	..	Neg.	0	Acute inflammation	Edema; friable
4	B. coli	2.0	0	13	D	0	..	..	Neg.	+	Empyema	Edema
5	B. coli	1.5	0	10	D	0	..	..	Neg.	0	No change	None
6	B. coli	1.0	0	41 K.	D	0	..	..	Neg.	0	Complete atrophy	Enlarged, edematous
7	B. coli	1.0	0	6	D	0	..	..	Neg.	+	Normal size and color	Enlarged, edematous
8	B. coli	0.5	0	2	D	0	..	..	Neg.	0	No change	Edema
9	B. coli	1.0	0	21 K.	D*	0	..	..	Neg.	0	No change	No change
10	B. coli	1.5	0	30	D*	+	1	..	Neg.	0	Acute inflammation	Enlarged
11	B. coli	1.0	0	8	D*	+	3	..	Neg.	0	Thickened walls	No change
12	B. coli	1.0	0	3	D	0	..	..	Neg.	+	Gangrenous	Enlarged, edematous
13	B. coli	0.75	+	6	D*	+	1	..	Neg.	+	Thick walls	Slightly enlarged
14	B. coli	0.1	0	20 hr.	D	0	..	..	Neg.	+	Gangrenous	Edematous
15	Strep.	0.5	0	20 K.	D	0	..	..	Neg.	0	Thick wall	Enlarged
16	Strep.	0.5	+	?	D	0	..	..	Neg.	+	Gangrenous	Slightly edematous
17	Strep.	0.3	+	2	D	0	..	Neg.	Neg.	+	Gangrenous	Enlarged
18	Strep.	0.3	0	2	D	0	..	Neg.	Neg.	+	Gangrenous	Enlarged
19	Strep.	0.3	0	6	D	0	..	Neg.	Neg.	+	Gangrenous	Enlarged

† D indicates downward trend; D* indicates downward trend with recovery later.

Necropsy.—This revealed a superficial wound infection and a localized peritonitis with adhesions in the gallbladder region. The gallbladder contained brownish-green mucoid material; it was not distended and the walls were slightly thickened. The liver was not enlarged.

Microscopic Examination.— The gallbladder showed destruction of the mucosa, thickening of the wall, increase of fibrous tissue, moderate infiltration with leukocytes, mononuclears predominating. The liver near the gallbladder showed moderate infiltration of leukocytes, chiefly mononuclears, around the bile ducts in the interlobular tissue. There were fatty infiltration and congestion of the parenchyma. At some distance from the gallbladder, the picture was the same but less extensive. Cultures of gallbladder contents and liver showed *B. coli.* The heart blood was sterile.

Dog 2.—The operation was performed as described previously. Two and one-half c.c. of *B. coli* culture was used. Symptoms of peritonitis appeared on the third day. The dog died on the fourth day.

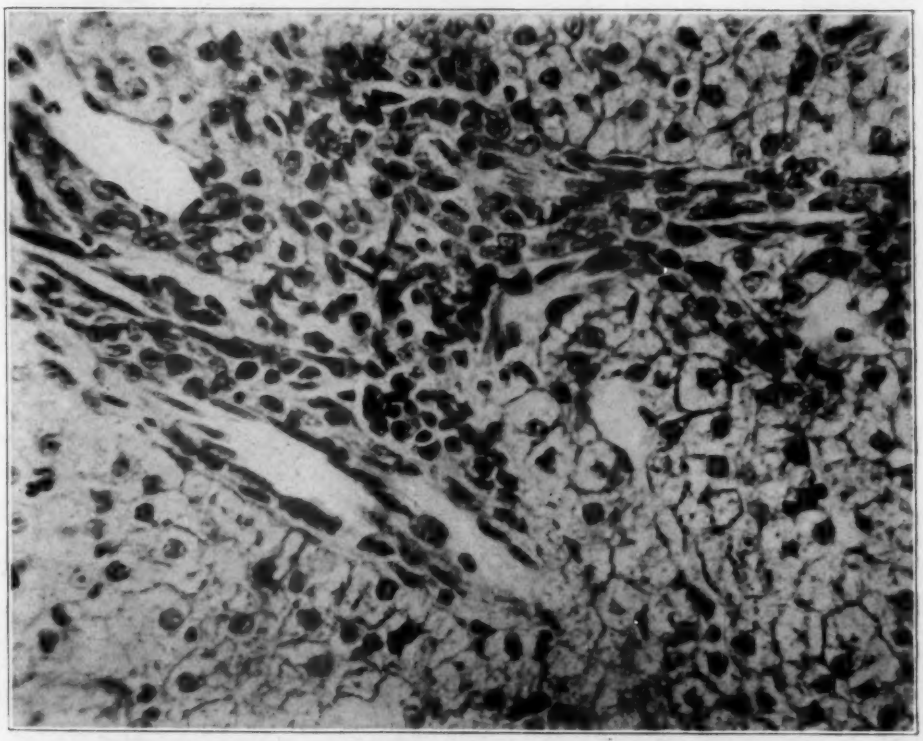

Fig. 6 (Dog 10).—Liver: rather numerous polymorphonuclear leukocytes and round cells under higher magnification.

Necropsy.— This revealed general peritonitis due to leakage through a needle hole in the gallbladder. The gallbladder was dark colored and friable. The liver was enlarged and edematous.

Microscopic Examination.—The gallbladder showed acute inflammation and gangrene. The liver (Fig. 2) showed moderate infiltration of the periportal spaces with polymorphonuclear leukocytes, and marked cloudy swelling of the parenchyma. Changes were most marked near the gallbladder. Cultures from the liver and gallbladder showed *B. coli;* smears from the peritoneum showed a gram-negative bacillus.

Dog 3.—Operation was performed as described. One c.c. of *B. coli* culture was used. The temperature rose to 104 F. on the fifth day and fell to 101 on the eighth day. The dog died on the ninth day. There was a loss of 2,200 gm. in weight.

Necropsy.—There was no general peritonitis. The liver was enlarged, edematous and bluish. The gallbladder showed no leakage of contents; the color was somewhat darker than normal; the contents were a yellowish, turbid mucus. There was bronchopneumonia.

Microscopic Examination.—The gallbladder showed acute inflammation with areas of necrosis; the mucosa was destroyed. There was moderate infiltra-

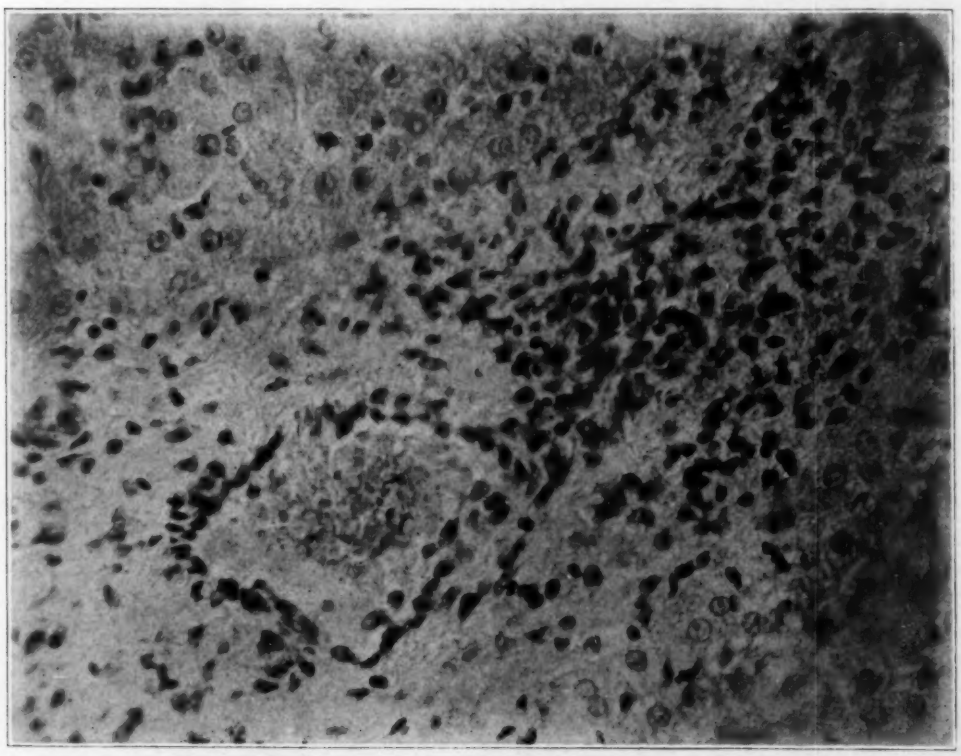

Fig. 7 (Dog 13).—Liver: infiltration of interlobular tissue with leukocytes.

tion of the interlobular tissue of the liver with polymorphonuclear cells, congestion and cloudy swelling. Sections of the liver before cholecystitis showed no leukocytic infiltration. Cultures of the liver and gallbladder contents showed *B. coli.*

Dog 4.—The usual operation was performed. Two c.c. of *B. coli* culture was used. The temperature rose to 103.6 F. on the fourth day, it was normal on the tenth day, with general improvement. The condition was worse on the twelfth day. The dog died on the fifteenth day. The loss in weight was 1,840 gm.

Necropsy.—There were general peritonitis and an extrahepatic abscess in the gallbladder region. The gallbladder was slightly distended and filled with

thick green pus, which escaped through the needle hole. The liver was markedly enlarged and edematous.

Microscopic Examination.—There was acute inflammation of the gallbladder with necrosis. The liver showed marked cloudy swelling with fatty infiltration; there was infiltration of the periportal spaces with polymorphonuclear leukocytes and edema. Liver section before cholecystitis demonstrated that it was normal. Cultures of liver and gallbladder contents showed *B. coli.*

Dog 5.—The usual operation was performed. One and one-half c.c. of *B. coli* culture was used. Death occurred on the tenth day.

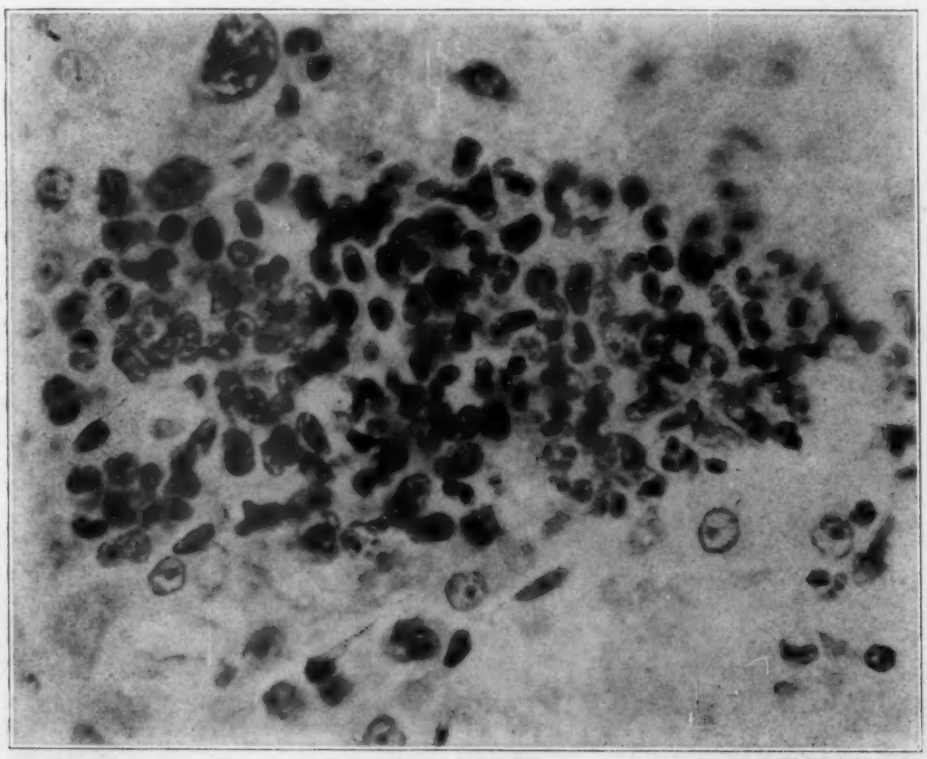

Fig. 8 (Dog 15).—Liver: marked pericholangitis under high magnification.

Necropsy.—There was no general peritonitis. The liver was slightly enlarged. The gallbladder was dark in color.

Microscopic Examination.—There was some thickening of the gallbladder walls, degeneration of the submucous layers in places, infiltration with mononuclears and polymorphonuclear cells. All sections of the liver showed slight periportal infiltration with mononuclear and polymorphonuclear cells, congestion and cloudy swelling. There was bronchopneumonia. Liver section was normal before injection. Cultures from the liver and gallbladder showed *B. coli.*

Dog 6.—The usual operation was performed. One c.c. of *B. coli* culture was used. The temperature rose to 104 F. on the fourth day and fell to 102

on the sixth day; the condition improved, but the appetite was poor. There was progressive loss of weight (2,500 gm.). The dog was killed on the forty-first day and necropsy was performed at once.

Necropsy.—The liver was enlarged to almost twice its size. There was no general peritonitis. The gallbladder was destroyed, the stump of the cystic duct alone remaining. There was a localized abscess at the site of the gallbladder. Smears showed gram-negative bacillus. The urinary bladder was distended with thick, strongly ammoniacal urine. The spleen was enlarged.

Microscopic Examination.—There was marked infiltration of the periportal spaces with polymorphonuclear and mononuclear cells, with cloudy swelling and

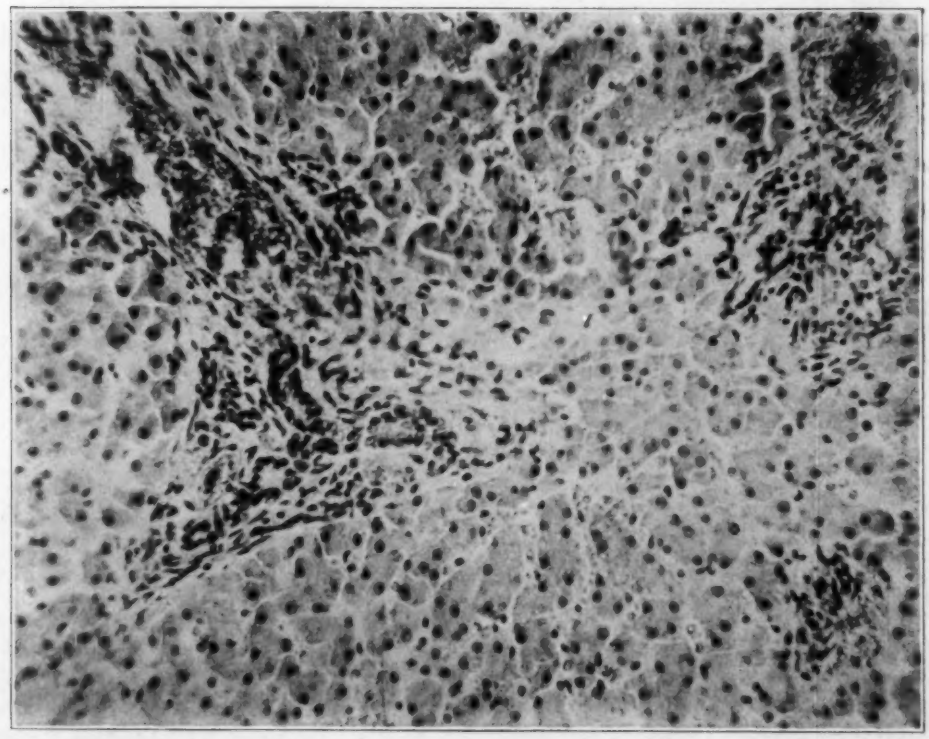

Fig. 9 (Dog 19).—Marked leukocytic infiltration of interlobular tissue near the site of the gallbladder. Compare with Figure 10.

necrosis in sections near the gallbladder site. Sections further removed showed a similar, but a much less extensive, picture. There was congestion throughout. Other organs showed cloudy swelling. Cultures of liver and heart blood showed *B. coli.*

Dog 7.—The usual operation was performed. One c.c. of *B. coli* culture was used. On the third day the animal had chills, a temperature of 104.5 F., anorexia, and it died on the sixth day.

Necropsy.—There was general peritonitis. The liver was enlarged and edematous. The gallbladder was not distended; all sutures and ligatures were functioning well.

Microscopic Examination.—There was acute inflammation of the gallbladder; the wall was gangrenous. The liver showed infiltration of interlobular tissues with polymorphonuclear cells throughout; there were miliary abscesses. The liver was normal before the production of cholecystitis. Cultures of the liver and gallbladder showed *B. coli.* The heart blood was sterile.

Dog 8.—The usual operation was performed. One-half c.c. of *B. coli* culture was used. Death occurred on second day.

Necropsy.—There was no general peritonitis. The liver was enlarged and edematous. The gallbladder was not distended. The ligatures and sutures were holding.

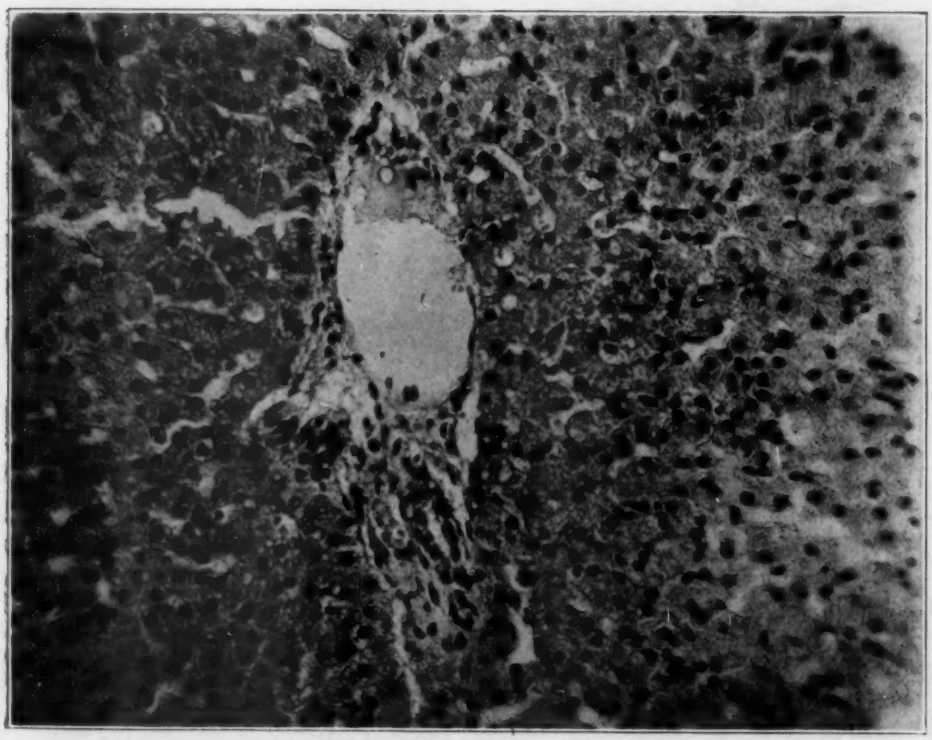

Fig. 10 (Dog 19).—Same liver as in Figure 9, showing moderate leukocytic infiltration in a portion of liver from the left lobe.

Microscopic Examination.—There was marked acute inflammation of the gallbladder. The liver showed infiltration of the periportal spaces with polymorphonuclear cells throughout; there were miliary abscesses. A section of the liver before injection was normal. Cultures of the liver and gallbladder showed B. coli. The heart blood was sterile.

Dog 9.—The usual operation was performed. One c.c. of *B. coli* culture was used. The temperature was 103.2 F. on the fourth day; 102.6 on the seventh day; 104.2 on the ninth day; 104.4 on the twenty-second day. There was a loss of weight of 300 gm. The dog was killed on the twenty-second day.

Necropsy.—There was no general peritonitis. The liver was slightly enlarged. The gallbladder was somewhat distended and filled with dark brown mucus.

Microscopic Examination.—The gallbladder (Fig. 4) showed the mucosa well preserved; the submucosa and muscularis and serosa, edematous and congested, and a small amount of mononuclear and polymorphonuclear infiltration. The liver (Fig. 3) showed infiltration of the periportal spaces with mononuclear and polymorphonuclear cells and cloudy swelling. The liver was normal before injection. Cultures of the gallbladder and liver showed *B. coli.* The heart blood was sterile.

TABLE 3.—Bacteriologic and Histologic Findings

Dog	Organism Recovered				Microscopic Changes	
	Gallbladder	Liver	Heart Blood	Peritoneum	Gallbladder	Liver
1	+	+	+	..	Acute inflammation; mucosa necrotic	Periportal infiltration; vacuolization
2	+	+	..	+	Acute inflammation; mucosa necrotic	Periportal infiltration moderate; cloudy swelling
3	+	+	0	0	Acute inflammation; mucosa necrotic	Periportal infiltration moderate; degeneration
4	..	..	..	..	Acute inflammation, marked	Periportal infiltration moderate; parenchymatous degeneration
5	+	+	+	+	Acute inflammation; mucosa destroyed	Periportal infiltration moderate; parenchymatous degeneration
6	..	..	..	..	Completely atrophied.....	Periportal infiltration round cells
7	..	..	..	..	Acute inflammation; mucosa gangrenous	Periportal infiltration; parenchymatous degeneration; congestion
8	..	..	..	..	Acute inflammation; mucosa gangrenous	Periportal infiltration; scattered abscesses
9	+	+	0	0	Acute inflammation, slight...	Periportal infiltration; many polymorphonuclears
10*	+	+	0	0	Acute inflammation.....	Periportal infiltration; fatty degeneration
11*	+	+	0	0	Acute inflammation.....	Periportal infiltration; focal necrosis
12	+	+	..	+	Acute inflammation; marked gangrene	Periportal infiltration; parenchymatous degeneration
13*	+	+	0	0	Acute inflammation, marked	Periportal infiltration; parenchymatous degeneration
14	..	..	..	..	Acute inflammation, gangrenous	Periportal infiltration moderate; parenchymatous degeneration
15	..	..	..	..	Acute inflammation.....	Periportal infiltration; many polymorphonuclears
16	+	+	0	0	Acute inflammation, gangrenous	Periportal infiltration; many polymorphonuclears
17	+	+	+	+	Acute inflammation, gangrenous	Periportal infiltration; many polymorphonuclears
18	+	+	+	+	Acute inflammation, gangrenous	Periportal infiltration; many polymorphonuclears
19	..	..	..	..	Acute inflammation, gangrenous	Periportal infiltration; parenchymatous degeneration

* Compare with Table 1.

Dog 10.—The usual operation was performed. One c.c. of *B. coli* culture was used. There was an uneventful recovery. The temperature was 103.2 F. on the third day; 104 on the fifth day and normal on the sixteenth day. On the twenty-ninth day a second operation was attempted. At this time the original incision was well healed; there were many adhesions around the gallbladder; the liver was slightly enlarged; the gallbladder was practically empty and small and the walls were thickened and white. The ligatures were holding. A section from the liver is shown in Figure 5. Blood was taken for agglutination tests (Table 3). The animal died the following day.

Necropsy. — This revealed bronchopneumonia. The condition of the liver was practically the same as at the second operation. There was no general peritonitis.

Microscopic Examination. — There was subacute inflammation of the gallbladder. The reaction was chiefly polymorphonuclear; the wall was fibrous. All sections of the liver showed inflammation of the periportal sheaths similar to those shown in Figure 5. The heart blood was sterile.

Dog 11.—The usual operation was performed. One c.c. of *B. coli* culture was used. The recovery was uneventful. The temperature was 102.4 F. on the fourth day and normal on the ninth day. The second operation was per-

Fig. 11.—Normal dog's liver for comparison.

formed on the ninth day. The wound was healed; the liver was slightly enlarged. Cultures were taken from the right and left lobes, also sections. The gallbladder was not distended; was grayish-blue; the walls were thickened and removed; and it contained dark brown mucus. Blood was taken for agglutination tests (Table 3). The dog died later and the lungs showed bronchopneumonia. The condition of the liver was approximately the same as at the second operation.

Microscopic Examination.—The gallbladder had intact mucosa; it was slightly edematous; the walls were thickened and showed acute inflammation. Sections removed at the second operation showed edema of the interlobular connective tissue with possible increase seen in sections nearest the gallbladder,

central necrosis, cloudy swelling, marked infiltration of the periportal spaces with polymorphonuclear leukocytes throughout. Sections from other portions removed at necropsy showed a similar picture. The heart blood was sterile.

Dog 12.—Routine operation was performed. One c.c. of *B. coli* culture was used. The dog was very sick and died in three days.

Necropsy.—There was considerable free bloody fluid in the peritoneum and there was general peritonitis. The gallbladder was gangrenous, walled in between lobes of liver and contained thick, yellow pus. The liver was enlarged, slightly edematous and bluish in color. Cultures were taken from the extreme right and left portions. The lungs were clear. Death was due to acute peritonitis. Cultures from the gallbladder showed *B. coli,* staphylococcus and mixed culture; from the liver (right and left lobes) *B. coli,* and a large gram-positive bacillus.

Microscopic Examination.—The liver (before injection) showed no pathologic changes. After necropsy, Section A (at a distance from the gallbladder) showed moderate polymorphonuclear infiltration about the portal veins in places, and a few scattered polymorphonuclears around the bile capillaries; Section B (near the gallbladder) showed congestion with necrosis at the periphery of the lobules. Moderate polymorphonuclear infiltration was present in the periportal spaces. In the connective tissue of the stroma and scattered throughout the parenchyma were rod-shaped bodies having the appearance of bacilli. The gallbladder mucosa was almost destroyed. The muscular and serous coats were thickened, edematous, infiltrated with polymorphonuclears and plasma cells. There was an exudate of fibrin and polymorphonuclears outside the serosa.

Dog 13.—Usual routine was followed and 0.75 c.c. *B. coli* culture were injected. There was some leakage and soiling around the gallbladder. The dog made an uneventful recovery. At the second operation the abdomen was opened. The omentum was found wrapped around a mass at the gallbladder site. The mass consisted of gallbladder walled in between lobes of liver and the first and second part of the duodenum. There was no free fluid in the peritoneum and no other adhesions. The liver was slightly enlarged and normal in color. There were numerous adhesions between the liver and abdominal wall, and the liver and the diaphragm. The adhesions were broken. The gallbladder was bluish-white; the walls were thickened and friable. A hole was torn in the gallbladder on manipulation and thick, greenish, gelatinous material oozed out. The hole was closed with purse-string sutures. Stab-cultures and sections were taken from the liver. One c.c. of twenty-four-hour *B. coli* broth culture was injected into the repaired gallbladder. The intestine was opened to obtain the culture. It was closed with purse-string sutures, The abdomen was closed. There were many bleeding points in the separated adhesions. The dog died on the following day.

Necropsy.—There were many freshly formed adhesions in the abdominal viscera; the liver was normal. There was bronchopneumonia. A section of the liver was taken. Death was due to bronchopneumonia. Cultures from the gallbladder showed *B. coli;* from the liver (left lobe) *B. coli;* from the liver (right lobe) *B. coli;* from the intestine (*a*) *B. coli,* and mixed culture; from intestine (*b*) *B. coli,* and mixed culture (Table 3).

Microscopic Examination.—The liver (before injection) showed no pathologic changes. After necropsy there was marked infiltration of the periportal spaces with round cells, plasma cells and polymorphonuclears (Figs. 7 and 8).

The gallbladder showed extremely acute inflammation, marked leukocytic infiltration and hemorrhage.

Dog 14.—The routine operation was performed and 1 c.c. *B. coli* culture was injected. The dog died twenty hours after operation.

Necropsy.—There was a large amount of free bloody fluid, slightly bile-tinged, in the abdomen. There was diffuse hemorrhagic peritonitis. The liver was dark and slightly edematous. The gallbladder was walled in between lobes of the liver; the distal end of the cystic duct was free; the ligature was off, and there was slight oozing of bile from the duct.

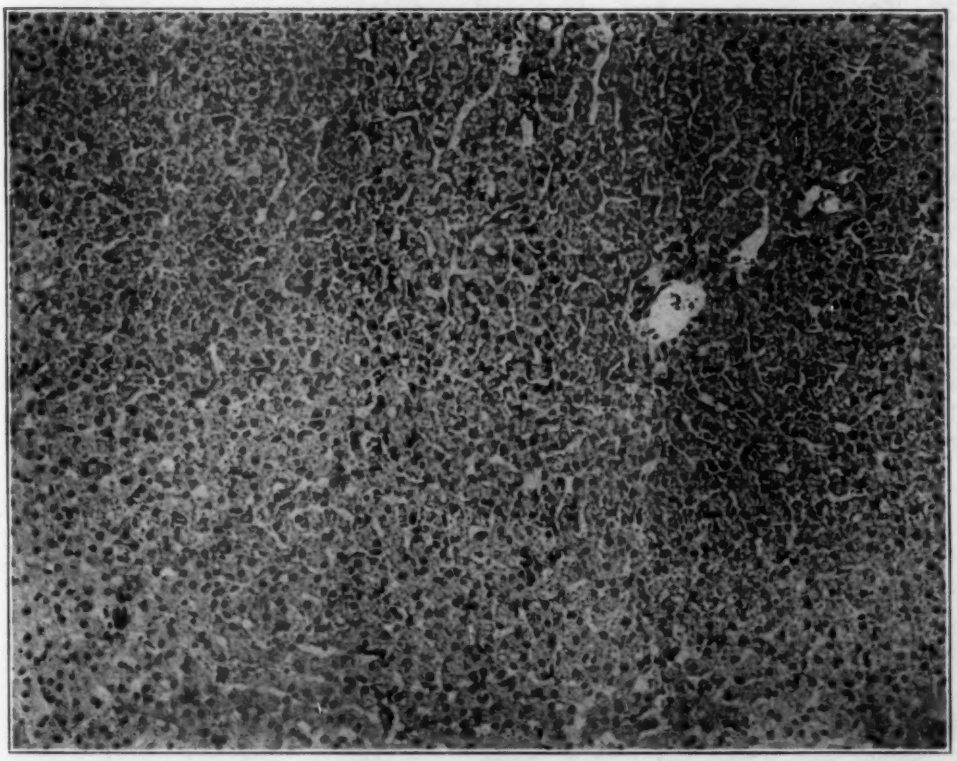

Fig. 12.—Normal dog's liver for comparison.

Microscopic Examination.—The liver showed marked loss of architecture; the cells were swollen and edematous. The picture was that of reaction to peritonitis with slight periportal infiltration, beginning stage. The gallbladder mucosa was degenerated and sloughing; there was acute inflammation; the muscular and serous coats were thickened, edematous and infiltrated with polymorphonuclears.

SERIES II. NONHEMOLYTIC STREPTOCOCCUS

Dog 15.—The usual routine operation was performed and 0.5 c.c. nonhemolytic streptococcus was injected. The cystic duct and vessels were ligated with two ligatures and cut between. The dog had a stormy course. It was killed twenty days after operation.

Necropsy.—The sinus at the upper pole of the wound was discharging pus. There was no free fluid in the peritoneum. The gallbladder was walled in between the lobes of the liver and omentum; the first part of the duodenum was bound in a mass of adhesions. The gallbladder was white, contained clear, thick, yellowish mucus with a small amount of purulent exudate at the base. The liver was enlarged and normal in color. There were several abscesses about the gallbladder site. The lungs showed multiple abscesses. A culture from the liver showed streptococcus (nonhemolytic) both from the abscess as well as from the interior of the right lobe at a distance from the abscess. The gallbladder showed streptococcus (nonhemolytic).

Microscopic Examination.—The liver (before injection) showed no changes. Sections of the liver after injection showed periportal infiltration with general parenchymatous degeneration (Figs. 7 and 8). The gallbladder showed acute inflammation. There was bronchopneumonia.

Dog 16.—The usual routine operation was performed; 0.5 c.c. nonhemolytic streptococcus was injected. The duct was ligated with two ligatures and cut between. The dog died two days after the operation.

Necropsy.—The abdomen was full of free bloody fluid; there was general peritonitis. The liver was dark red, friable and slightly edematous. The gallbladder was black and distended and full of black fluid. The peritoneum was dull red throughout. Culture was made of the heart's blood, which was negative. The gallbladder showed nonhemolytic streptococcus; the liver, nonhemolytic streptococcus. A smear from the peritoneal fluid showed gram-negative and gram-positive rods; no streptococci.

Microscopic Findings.—The liver (before injection) showed no change. Sections (at necropsy) next the gallbladder, showed on one side a layer of inflammatory exudate with polymorphonuclears, plasma cells and fibrin. The inflammation extended into the liver substance, the bile spaces and the periportal areas being infiltrated with polymorphonuclears. The reaction became less severe farther away from the site. Sections at various points in the liver showed cloudy swelling, congestion and varying degrees of polymorphonuclear infiltration. The gallbladder showed edema and necrosis of the mucosa.

Dog 17.—The usual routine operation was performed and 0.3 c.c. of nonhemolytic streptococcus culture was injected. The duct was ligated twice and cut between the ligatures. The dog died in two days.

Necropsy.—The abdomen contained a large amount of free bloody fluid. The liver was enlarged and dark. The gallbladder was walled in between lobes of the liver and plastered down with omentum. It was distended, large, brown, gangrenous and filled with dark brown mucus. The heart was dilated. Culture was made of the heart's blood. Cultures of the liver before production of cholecystitis were sterile. At necropsy the peritoneal fluid showed streptococcus; the gallbladder, streptococcus; the liver, streptococcus, and the heart's blood, streptococcus.

Microscopic Findings.—The liver before injection showed no changes. Sections (at necropsy) showed cloudy swelling, congestion, slight infiltration of polymorphonuclears into the periportal spaces. Sections from the fundus and neck of the gallbladder showed complete necrosis.

Dog 18.—The routine operation was performed; 0.3 c.c. of nonhemolytic streptococcus was injected. There was a double ligature, cut between. The dog died two days after operation.

Necropsy.—This revealed a small amount of free bloody fluid in the peritoneal cavity. There was general, diffuse, acute peritonitis. The gallbladder was surrounded by lobes of the liver; it was small, dark, gangrenous and contained thick, black material. The liver was enlarged and dark red, especially around the gallbladder. Cultures at necropsy from the peritoneum showed streptococcus; from the liver, streptococcus; from the gallbladder, streptococcus, and from the heart's blood, streptococcus.

Microscopic Findings.—The liver, before injection, showed no change. Sections (at necropsy), showed cloudy swelling throughout with areas of central necrosis. There was a collection of round cells and polymorphonuclears in the periportal areas. The gallbladder mucosa was necrotic and it was infiltrated with polymorphonuclears.

Dog 19.—The usual routine was performed; 0.3 c.c. of nonhemolytic streptococcus culture was injected. Double ligatures were made and cut between the ligatures. The dog died six days after operation.

Necropsy.—The abdomen contained a large amount of free bloody fluid; there was diffuse peritonitis. The first portion of the duodenum was wrapped in a mass of omentum which bound the lobes of the liver around the gallbladder. The liver was enlarged with areas of superficial necrosis. The gallbladder was gangrenous and contained thick dark green fluid.

Microscopic Examination.—The liver, before injection into the gallbladder, showed no change. Sections (at necropsy) showed loss of architecture, parenchymatous degeneration, periportal infiltration of polymorphonuclears. The gallbladder showed almost complete necrosis (Figs. 9 and 10).

THE EFFECT OF COMBINED RADIATION AND HEAT ON NEOPLASMS *

G. L. ROHDENBURG, M.D., AND FREDERICK PRIME, M.D.
NEW YORK

As a result of animal experimentation and clinical experience, it has become evident that extremely large doses of radiation are necessary to kill neoplastic cells which are located at any considerable distance from the surface of the body. Such dosage is often productive of untoward effects on contiguous and intervening normal tissues, may induce a serious general reaction, and has been known occasionally to cause death. If the lethal action of radiant energy on the tumor cell could be supplemented by that of some other nocive agent which does not increase the general or local damage to the body, it might be possible to extend the field of application of radiation to tumors at present inaccessible.

The fact that, in many instances, spontaneous recession in human tumors was observed to follow a period of fever led us, in 1916, to try the effect of raising the temperature of animals with implanted tumors. This experiment failed because mice and rats rapidly succumb to moderate degrees of heat.

The experiments subsequently recorded by Bovie,[1] in which he showed that proteins exposed to ultraviolet light coagulated at a much lower temperature than did untreated protein, again suggested the idea that this heat might be applied clinically and serve as a method of increasing the therapeutic range of radiation. It was, therefore, to determine the value and limitations of a combination of radiation and heat as applied to the treatment of cancer that the experiments here recorded were planned.

The use of a combination of the two physical agents, radiation and heat, is not entirely novel. The effect of low degrees of heat alone on transplantable animal tumors has been studied by Jensen,[2] Loeb,[3] Clowes[4] and R. A. Lambert,[5] and, more recently, in this

* From Columbia University, George Crocker Special Research Fund, F. C. Wood, Director.

1. Bovie, W. T.: J. Cancer Research **5**:88 (Jan.) 1920.
2. Jensen: Centralbl. f. Bakteriol., I Abt. Orig. **34**:129, 1903.
3. Loeb: J. M. Research, N. S. **3**:62, 1902; Virchows Arch. f. path. Anat. **162**:345, 1903.
4. Clowes: Brit. M. J. **2**:1549, 1906.
5. Lambert, R. A.: Demonstration of the Greater Susceptibility to Heat of Sarcoma Cells as Compared with Actively Proliferating Connective-Tissue Cells, J. A. M. A. **59**:2147 (Dec. 14) 1912.

laboratory by Stevenson,[6] and it has been shown that neoplastic cells are relatively easily killed by this agent, although cancer cells are no more susceptible than are rapidly growing normal cells. The relationship existing between the degree of heat and the length of time that it was applied has not been thoroughly investigated, though Stevenson's experiments were directed toward this question. The actual cautery was used as a therapeutic agent in cancer by the ancients, and, more recently its use has been revived in modified form by Percy [7] and New.[8] The combination of high degrees of heat and radiation was first applied by de Keating-Hart,[9] and in this instance the heat was produced by the high frequency electrical current.

Fulguration and diathermy were also used, either singly or in combination with radiation, by Iredell and Turner,[10] Harner,[11] and Beebe and Van Alstyne.[12] All these authors applied the method in a manner widely different from that used in the experiments described herewith. Schmidt,[13] however, advanced the theory that heat sensitizes the tissues to radiation and stated that this sensitization can be accomplished by diathermy. He announced that he would publish his clinical data later, but we have not been able to find any subsequent article by this author dealing with his experience.

Theilhaber [14] described a method very similar to the one we have employed. In his experience greater lethal effect was produced when tissues were radiated first and heated subsequently. He also drew attention to the fact that normal as well as malignant tissues were sensitized. Theilhaber used large electrodes and an amperage which approximated that used by us, but did not apply the current for so long a period of time as we did. He described several treated cases but gave no detailed data.

The present investigations may be considered under several headings: (*a*) the effect of heat upon fragments of transplantable tumor in vitro; (*b*) the effect of a combination of radiation and heat upon

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6. Stevenson, H. N.: J. Cancer Research **4**:54 (Jan.) 1919.

7. Percy, J. F.: Surg., Gynec. & Obst. **22**:77 (Jan.) 1916.

8. New, G. B.: Treatment of Malignant Tumors of the Antrum, J. A. M. A. **74**:1296 (May 8) 1920.

9. De Keating-Hart: La fulguration et ses résultats dans le traitement du cancer, d'après une statistique personnelle de 247 cas, Paris, 1909.

10. Iredell, C. E., and Turner, P.: Proc. Roy. Soc. Med. (Sect. Electrotherap.) **12**:23 (June) 1919.

11. Harner: Brit. M. J. **2**:1017, 1914.

12. Beebe and Van Alstyne: Surg., Gynec. & Obst. **18**:438, 1914.

13. Schmidt: Fortschr. a. d. Geb. d. Röntgenstrahlen **14**:135, 1909.

14. Theilhaber, Adolf: Die Entstehung und Behandlung der Karzinome, Berlin, S. Karger, 1914.

fragments of transplantable tumor in vitro; (*c*) the effect of heat upon spontaneous tumors in vivo, and (*d*) the effect of a combination of heat and radiation upon spontaneous tumors in vivo.

THE EFFECT OF HEAT UPON FRAGMENTS OF TRANSPLANTABLE TUMOR IN VITRO

Although the recorded experiments in which the action of heat has been studied are extensive, there is still some confusion as to the death point of the neoplastic cell. This confusion is due in part to a lack of appreciation of the correlation between the degree of

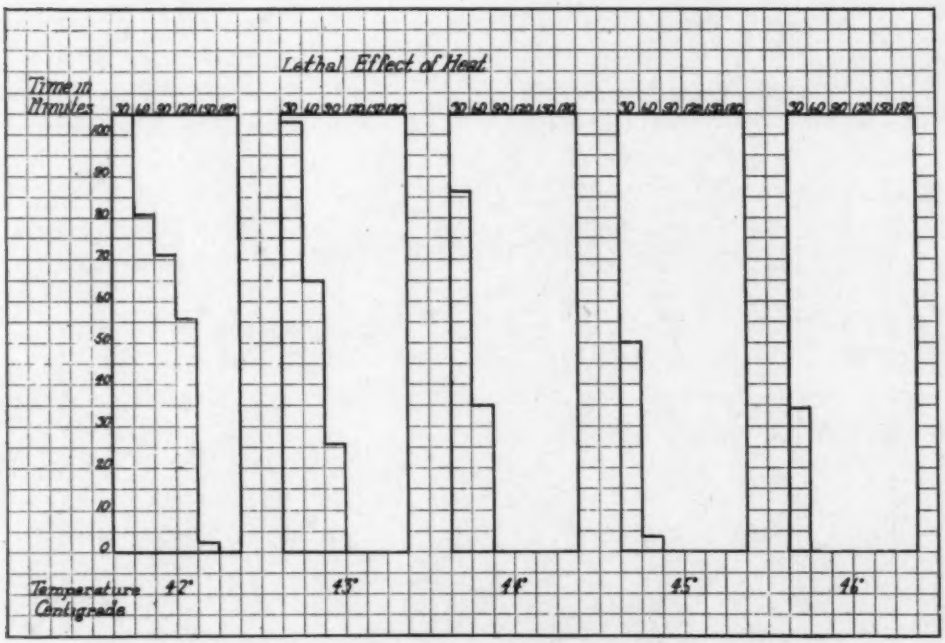

Chart 1.—Lethal effect of heat on tumor cells.

temperature used and the period for which heat is applied. Another factor influencing the results so far published is the biology of the tumors employed. In determining the lethal effect of any agent upon a tumor cell, it is essential that a tumor be used which does not undergo spontaneous recession after inoculation in any considerable percentage of cases. The Crocker mouse sarcoma 180 meets this requirement, since observations extending over five years and comprising about 5,000 tumors show an average of 98 per cent. of "takes" with less than 1 per cent. of spontaneous recessions.[15]

15. Prime: Paper read before the American Association for Cancer Research, April, 1920.

The technic employed in the first series of experiments was as follows: All manipulations were performed under sterile conditions. A tumor was cut into small fragments for inoculation (0.002 to 0.003 gm.). These fragments were placed in test tubes containing Ringer's solution which had been previously raised to the temperature of the experiment. The test tubes with their contents were then placed in a water bath, and kept at the given temperature for the time period specified. At the expiration of this period the Ringer's solution was poured off and cold Ringer's solution substituted to check further action of the heat. As controls, similar fragments of the same tumor were placed in cold Ringer's solution for the period of time that the

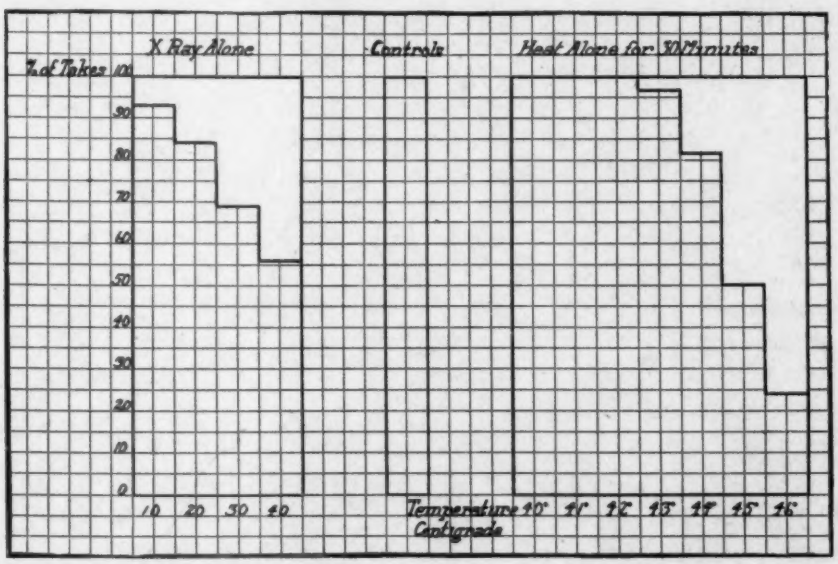

Chart 2.—Effect of combined heat and radiation on fragments of transplantable tumor in vitro.

other fragments were exposed to heat. Both sets were then inoculated subcutaneously into mice in the usual fashion, a trocar and needle being used. In this manner, many series of twelve animals each were inoculated, the grand total, including controls, being 2,684 animals. The temperatures to which the tumors were exposed were 42, 43, 44, 45 and 46 C., and the time periods with each fixed temperature were 30, 60, 90, 120, 150 and 180 minutes. The animals were kept under observation for five weeks after inoculation, when the percentage of "takes" was determined. The data are graphically presented in Chart 1.

With a temperature of 42 C., the first lethal effect is evident after sixty minutes' exposure and from this point on there is a rapid increase in the lethal effect until at the 180 minute period it attains the maximum

of 100 per cent. With temperatures higher than 42 C., the lethal effect is in evidence sooner and attains its maximum with shorter periods of exposure until at 46 C. a thirty minute exposure is lethal in more than 60 per cent. of cases.

THE EFFECT OF COMBINED HEAT AND RADIATION ON FRAGMENTS OF TRANSPLANTABLE TUMOR IN VITRO

Having determined the lethal point for the Crocker mouse sarcoma 180 with different degrees of heat at different time intervals, and having the advantage of the results of the previous work of Wood and Prime,[16] who, using the same tumor strain, determined the lethal effect of radiation, we next employed a combination of the two agents, each in sublethal doses.

The technical steps in the experiments in this series were similar to those previously described. The heat exposures were made as previously stated, except that in combining the two physical agents, exposures were made only at 42, 43 and 44 C. for the fixed period of thirty minutes. This time interval represented the threshold of lethal effect at each of these temperatures.

The tumor to be exposed to radiation was cut into small fragments as before, and the fragments were placed in glass dishes with enough cold Ringer's solution to keep them moist, and were covered with a sterile cover glass. The radiation dose was 85,000 volts, 5 milliamperes, with a 3 mm. aluminum filter at a distance of 23 cm. for 10, 20, 30 and 40 minutes.

In these experiments, we again used repeated series of twelve animals each, the grand total being 3,248 animals. The series were as follows: (*a*) animals inoculated with untreated portions of the tumor; (*b*) animals inoculated with fragments treated with heat alone; (*c*) animals inoculated with fragments treated with roentgen ray alone; (*d*) animals inoculated with fragments treated with radiation first and heat directly afterward; (*e*) animals inoculated with fragments treated with heat first and radiation directly afterward. As before, the animals were observed for five weeks after inoculation and the percentage of "takes" was then determined. The data are graphically presented in Charts 2 and 3.

The untreated controls showed 100 per cent. "takes," the animals inoculated with fragments exposed to one erythema dose showed 93 per cent. "takes" and those inoculated with fragments exposed to three erythema doses, 68 per cent. The animals inoculated with frag-

16. Wood, F. C., and Prime, Frederick: Ann. Surg. **62**:751, 1915; Lethal Dose of Roentgen Ray for Cancer Cells, J. A. M. A. **74**:308 (Jan. 31) 1920.

ments treated solely with heat showed 82 per cent. "takes" when the exposure had been to 44 C., and 100 per cent. when the exposure had been to 42 C.

When both heat and radiation are applied in sublethal dose, and it makes but little difference which is applied first, there is a marked lethal effect. Thus, while a temperature of 42 C. for a period of thirty minutes applied after one erythema dose has a lethal effect of but 10 per cent., and when the order of application of the agents is reversed no lethal effect is noted, a temperature only one degree higher produces a lethal effect of 76 per cent. in one instance and 91 per cent.

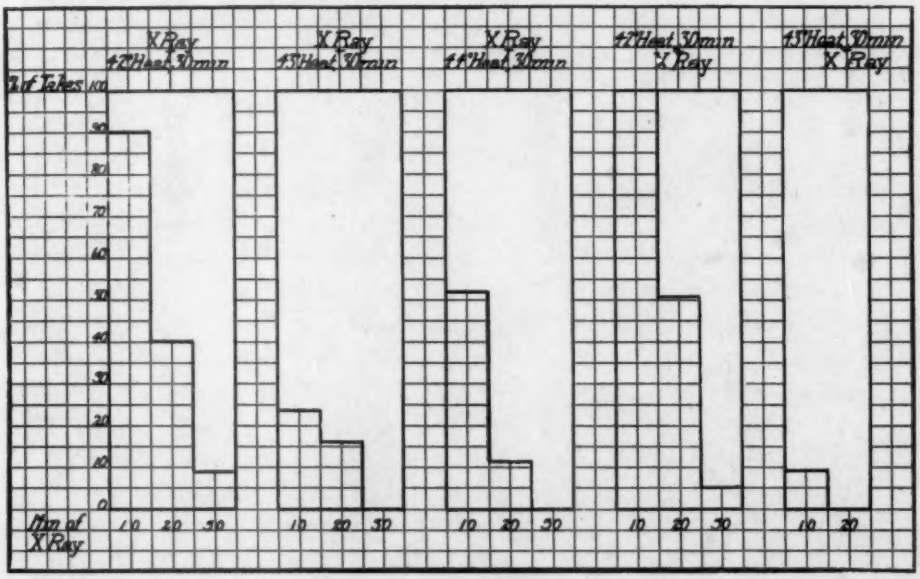

Chart 3.—Effect of combined heat and radiation on fragments of transplantable tumor in vitro.

in the other. The lethal effect of radiation combined with heat is not so marked at 44 C. as at the lower temperature of 43 C. This we have interpreted as an evidence of stimulation comparable to the stimulation which occurs with certain sublethal doses of radiation. The maximum lethal effect of 100 per cent. is obtained with three erythema doses and thirty minutes' exposure to 43 C., the radiation being applied first, or with two erythema doses and thirty minutes' exposure to 43 C., the heat being applied first. The slight difference is probably of no significance. According to the results obtained by Wood and Prime, five erythema doses alone are required to kill the cells of mouse sarcoma 180; and our previously described experiment with the

same tumor strain shows that 120 minutes' heating at 43 C. is required to kill. The combination of a given sublethal dose of the two agents, therefore, produces the same effect as four times the dose of heat when used alone, and as five times the dose of radiation when used alone.

THE EFFECT OF HEAT UPON TUMORS IN VIVO

Since the results of biologic experiments in vivo often are different from those of the same experiments in vitro, these observations were repeated on tumors in the animal body. For this reason in the later experiments, the tumors were heated by diathermy, a term applied to an alternating current of high frequency used so as to create heat in the tissues through which it passes. The degree of heat obtained,

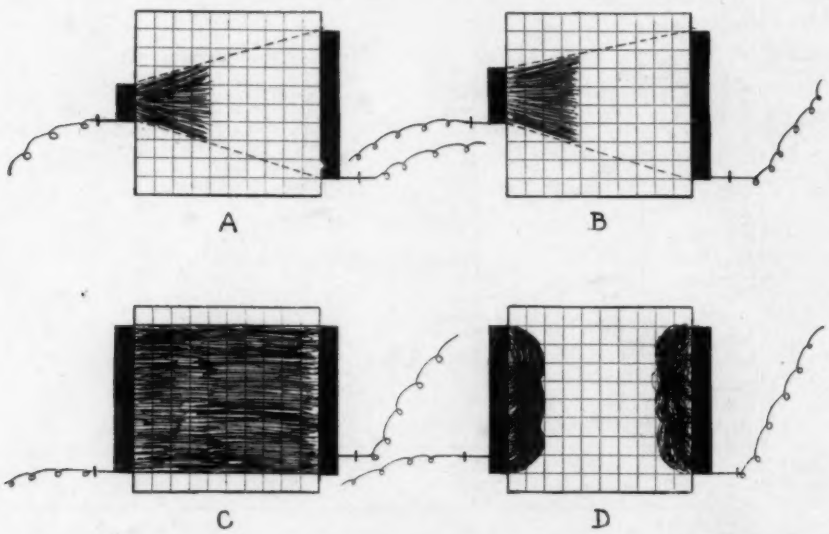

Chart 4.—Effect of electrode shape and current strength on intervening tissues: *A*, 10 ma., ten minutes; *B*, 100 ma., four minutes; *C*, 10 ma., ten minutes; *D*, 100 ma., four minutes. Strong current for a short time gives a superficial action (*B, D*). Weak current for a long period gives deeper action (*A, C*). If both electrodes are of the same area and the current is weak, the heated zone is cylindric (*C*). If one electrode is small or the current is strong, the heated zone is localized about the electrode (*B, D*).

and, hence, the physical changes which occur in the tissues are dependent on two conditions: (*a*) amperage and (*b*) shape and area of the electrode. By varying these two, all effects from a slight increase in temperature to charring of tissues are obtainable.

It was the aim in combining the two agents, radiation and heat, to produce relatively low degrees of temperature, and to continue them over relatively long periods, and it is in these two points that

the method employed differs from all others which have been recorded. Thus, a recent study of this subject [17] is based upon the use of 3 amperes of current for fifteen seconds with very small electrodes, and the conclusion is reached that the method is valueless. To anticipate, in order to indicate the difference between the method used in the present experiments and those in the work just referred to, it may be stated that we have employed 40 milliamperes for a period of twenty minutes with relatively large electrodes. The previous worker reported a typical burn reaction, while the tissues we have treated show no such changes. The temperatures we have employed are also very much lower than those used in the Percy or in any other cauterization or fulguration methods which have been advocated.

As has been stated before, the degree and type of effect of the heat generated by the high frequency current is dependent upon the shape of the electrode. Chart 4 illustrates the points which are of importance. If the electrodes are of unequal size, as in *A*, and the current weak, there will develop a zone of reaction penetrating for a considerable distance into the tissues but attaining its maximum at the small electrode. On the other hand, if the current is increased in strength, the effect is directly localized about the small electrode, as in *B*. If the electrode is of equal size and a weak current is employed, as in *C*, there is a cylindric area of action between the two electrodes, while if the current is strong there is a marked action about each electrode, but none in the depths of the tissues, as in *D*.

While the facts just stated are common knowledge, a search of the literature revealed no data on the amount of current necessary to produce a given rise in temperature. In order to determine this, diathermy was applied to various thicknesses of bone-free meat. The initial temperature of the meat before the application of diathermy was in each instance 10 C. and the given amperage was allowed to flow for a period of twenty minutes. A thermometer was placed in the tissue midway between the electrodes, and the temperature was noted every three minutes. The amperage is based on the square area of one electrode, and both electrodes were of the same shape and size.

Chart 5 presents a curve constructed on the data thus obtained, and while it is far from mathematically accurate, it is close enough for practical purposes. With an electrode with a surface area of 2.5 by 2.5 cm. and with 10 milliamperes, the increase in temperature

17. Stephan, Erich: Histologische Untersuchungen über die Wirkung der Thermopenetration auf normale Gewebe und Carcinom, Beitr. z. klin. Chir. **77**:382, 1912.

produced by twenty minutes' application of current in varying thicknesses of tissue is as shown by the curve. If electrodes of twice this size are used, then the heat produced is one-half that recorded in the chart; and if living instead of dead tissues are used, the rise in temperature is approximately double that indicated on the chart. Why this is so we do not know. The increase of temperature in dead tissue for the first ten minutes of current flow is rather slow, but for the second ten minutes is more rapid; and while a continuation of

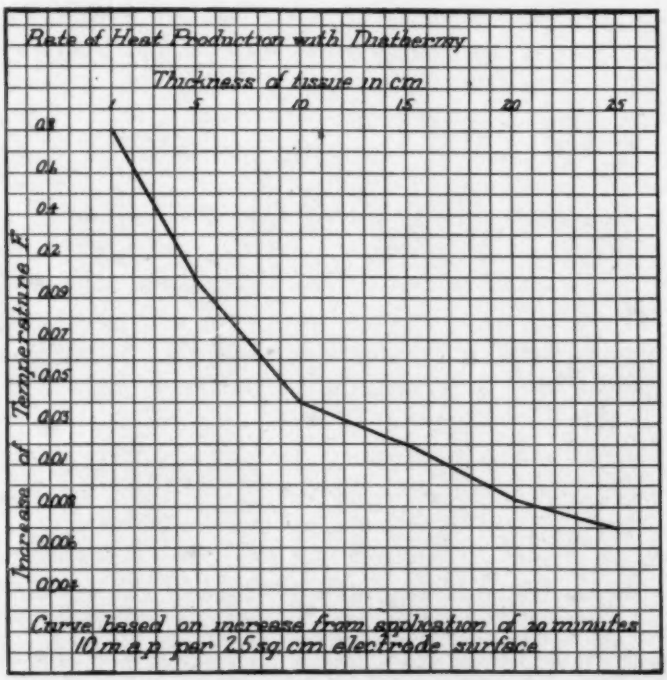

Chart 5.—Amount of current necessary to produce a given rise in temperature.

the same amount of current for more than twenty minutes gradually increases the temperature, this increase is extremely slow, and for practical purposes can be disregarded.

In applying the current to human beings the procedure is as follows: Electrodes of equal size and the same shape are cut from block tin. Gauze compresses, four or five folds thick, are moistened with water and applied to the skin, the compresses being made large enough to allow of a 4 cm. margin outside the electrode. Sparking due to imperfect contact of the electrode or to electrode connections with the skin must be avoided, for sparking is painful and produces burns.

The amperage used is roughly fixed by determining in centimeters the square area of one electrode, dividing this by 6 (the square area of the electrode used in Chart 5), dividing the result by 2 (if the tissues are living), and multiplying the result thus obtained by 10 (the amperage used in the experiment on which Chart 5 is based). The amperage may, however, be more easily regulated by the sensation of the patient. Sparking being obviated, the amperage is increased until the patient states that the degree of heat is uncomfortable; the amperage is then decreased until the patient feels perfectly comfortable with the degree of heat that is being produced. The treatment is timed from twenty minutes after the current is turned on, so that, the average treatment being from thirty to forty minutes, the total exposure is approximately one hour. Our experiments have shown that low degrees of heat (41 C.) produce the same results as high degrees (46 C.), but to be effective the lower temperature must be applied for longer periods. This should be borne in mind when treatments are given.

For the purposes of histologic study of the changes in the tissues, a series of transplantable rat sarcomas and carcinomas were treated with diathermy (exposure twenty minutes); amperage, 40 milliamperes; area of electrode, 8 sq. cm.; depth of tissue, 5 cm. Some of the animals received but one treatment, and were killed at intervals ranging from twenty-four hours to one week after treatment; others received two, three and four treatments at two-day intervals, and were killed at intervals of from twenty-four hours to one week after the last treatment.

The histologic changes observed occurred in this sequence. Twenty-four hours after the treatment there was an intense congestion of all the small blood vessels of the tumor, most of them being from five to six times their normal diameter. This congestion was so intense as to give rise to a deep red color throughout the tumor; this occurred irrespective of whether the animal had had one or more treatments, and was demonstrable up to twenty-four hours after the last treatment. About three days after treatment, the cell outlines became obscure, though the nuclei still preserved their outline and staining qualities. Next the cytoplasm became decidedly acidophil, the tissues took the stains poorly and there was an evident karyorrhexis. About this period, some of the blood vessels became thrombosed, and vacuolation occurred in some of the cells, the connective tissue framework of the tumor standing out markedly owing to the degeneration of the parenchyma. At still later periods (three and six days) areas of liquefaction or massive coagulation necrosis were in evidence; and at the seventh day, replacement fibrosis began to be obvious arising from the

intact blood vessels at the periphery of the tumor or from the surrounding healthy tissue. Absorption of the necrotic material was extremely slow. It is interesting to note that while the untreated tumors showed an average of twenty mitotic figures to the field of a 12 mm. objective, a tumor treated but once showed no mitotic figures in 180 fields, twenty-four hours after treatment. Exposures

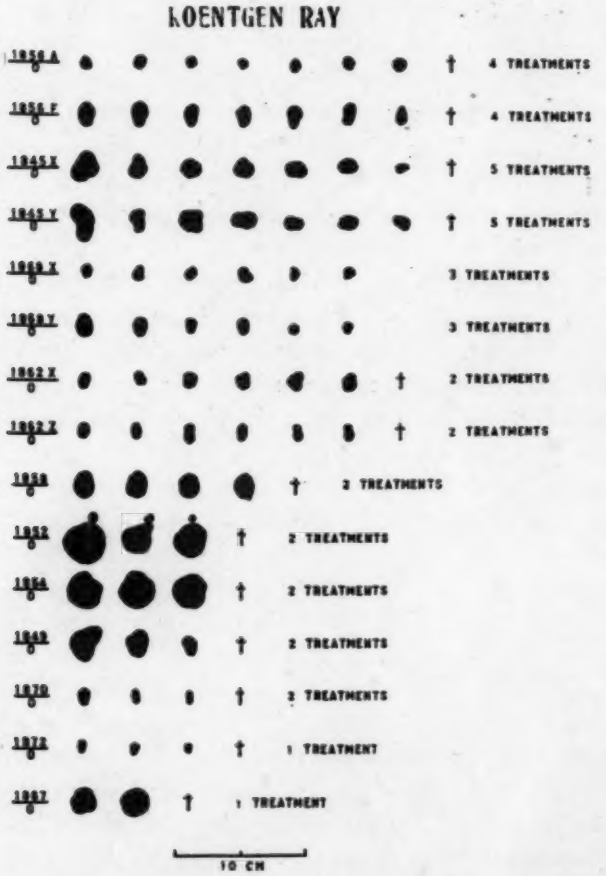

Chart 6.—Effect of combined heat and radiation on spontaneous tumors in vivo.

made at intervals more frequent than once in seven days did not increase the intensity of the reaction. Evidently, the damage done with one treatment cannot be duplicated until the neoplasm has had a chance to recuperate to some degree. There were no changes in the organs of the exposed animals which could be attributed to the treatment or to the absorption of dead material.

EFFECT OF COMBINED HEAT AND RADIATION ON SPONTANEOUS TUMORS IN VIVO

For the purpose of this investigation, spontaneous tumors in mice of the "Lathrop" stock were used. The animals of this breed are particularly prone to develop tumors of the breast and all those treated originated in that locality. Some of the tumors were treated with

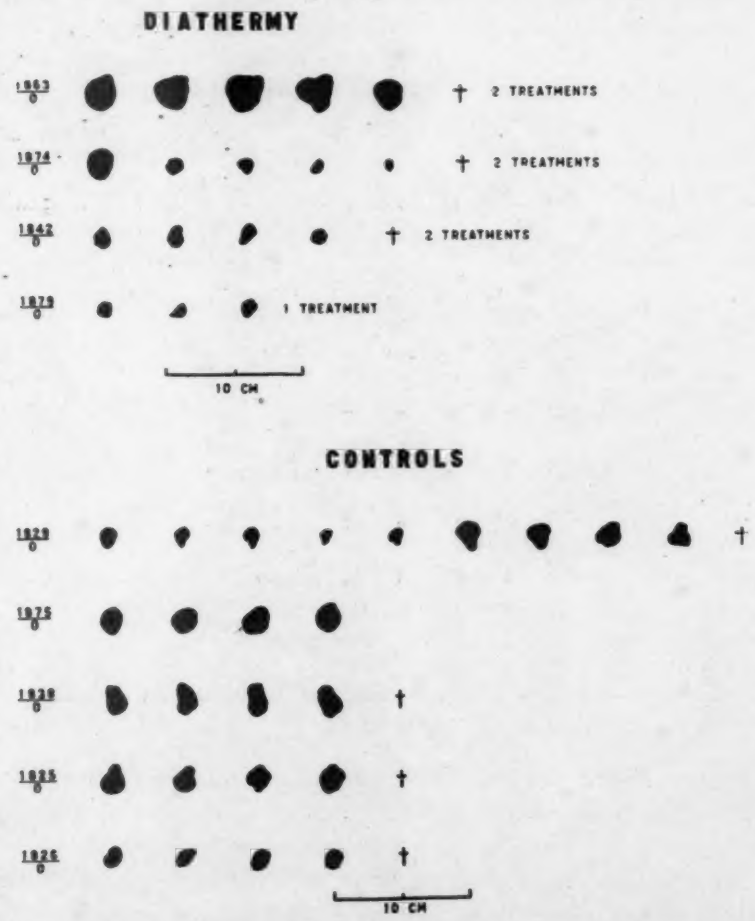

Chart 7.—Effect of combined heat and radiation on spontaneous tumors in vivo.

radiation alone, others with diathermy alone, and still others with a combination of the two agents. Radiation was given the tumor once in from seven to ten days, the distance being 23 cm. from the neoplasm, the rays filtered by 3 mm. aluminum with a voltage of 85,000 and 5 milliamperes through the tube for a period of twenty minutes.

All parts of the animal except the tumor under treatment were carefully screened by heavy lead. Diathermy was given through a 2.5 cm. square electrode for a period of twenty minutes with 40 milliamperes once in seven or ten days. When radiation and heat were both applied it was done in some instances on the same day, in other instances at twenty-four hour intervals; sometimes heat was applied first, while at other times radiation was used first. The interval between successive combination treatments was from seven to ten days.

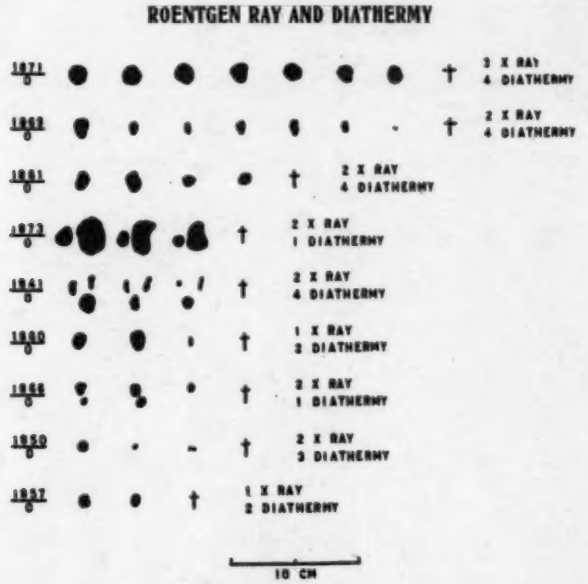

Chart 8.—Effect of combined heat and radiation on spontaneous tumors in vivo.

The results obtained are graphically shown in Charts 6, 7 and 8. The first column in each chart indicates the size of the tumor on commencing treatment, the other columns indicate the size of the tumor at subsequent weekly intervals. Tumors treated with diathermy or radiation alone show but little inhibition or recession in growth when compared to tumors treated by a combination of both of these agents.

CONCLUSIONS

Low degrees of heat applied for varying periods of time have a lethal action on neoplastic cells in vitro and this lethal action with proper dosage is effective in 100 per cent. of cases. Histologic examination of tumors which have been treated by diathermy reveals cellular changes similar to those observed in tumors exposed to radiation.

Wood and Prime have shown that any tumor may be killed by a sufficient dosage of either radium or roentgen ray; but that in many instances the patient will not survive the dosage necessary to bring about the death of all the cells of an internal, highly malignant carcinoma or sarcoma. Our experiments demonstrate that by combining radiation with an agent not so destructive to the organism the field of usefulness of radiotherapeutic measures may be extended.

The results obtained in the animal experiments show that the therapeutic range of radiation can be considerably increased.

While the principles worked out in the animal experiments here recorded are already being applied in the treatment of cases of neoplasia in human beings, the technical development of the method and the evaluation of the final results will require long and careful observation of the patients before its applicability can be demonstrated.

UNRECOGNIZED OCCUPATIONAL DESTRUCTION OF THE TENDON OF THE LONG HEAD OF THE BICEPS BRACHII *

ARTHUR WILLIAM MEYER, M.D.
PALO ALTO, CALIF.

In 1915 I reported [1] six instances of destruction of the tendon of the long head of the biceps. This destruction occurred between the region of the humeral tuberosities and the supraglenoid tubercle of the scapula. In five of these cases, the destruction of the tendon was complete and was accompanied by destructive changes in the capsule of the shoulder joint, on the acromion and the humeral tuberosities, in the glenoid cavity, on the head of the humerus, in the acromioclavicular joint, and even on the internal surface of the deltoid itself. In one case, the sixth, considerable portions of the articular capsule and the entire lesser tuberosity also were destroyed. Yet in this case, the tendon of the long head was only displaced anteriorly and downward, lying along the anterior margin of the glenoid cavity and then passing to the intertubercular sulcus, which it reached a centimeter distal to the tuberosities. None of these articulations contained any deposits or other evidences of the existence of recent effusion, and the whole picture suggested that the condition resulted from a low grade, long-standing process.

Since the destruction not only of the capsule and the tendon but even of the articular cartilage and also the changes in the adjacent bone were so extensive, it is evident that the process could not have been acute. No evidence of surgical intervention was present in any of these cases, hence the condition could not have been accompanied by much if any suppuration even in the acute stage of the process, if such there was.

It is regrettable that clinical histories of these cases were unobtainable, for they might have thrown light on the probable cause and the nature of these conditions, for similar findings were not found recorded in the literature up to that time, nor have I learned of similar cases since. Such cases apparently do not appear in clinics and dispensaries, for pathologists and orthopedic surgeons seem to be unfamiliar with them. Nor have I learned that similar cases have been observed in other anatomic laboratories, but if I have overlooked such

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* From the Department of Anatomy, Leland Stanford Junior University School of Medicine.

1. Meyer, A. W.: Anatomical Specimens of Unusual Clinical Interest. (2) The Effect of Arthritis Deformans (?) on the Tendon of the Long Head of the Biceps, Am. J. Orthop. Surg. **13**:91 (July) 1915.

Fig. 1.—Humeri of the first six specimens, bisected longitudinally in a plane approximately parallel to the condylar articular surface.

a report I trust that my attention will be called to it. Since the condition is so surprising it seems strange that the specimens reported in 1915 have not arrested attention sufficiently to have resulted in direct confirmation from other sources, for I have observed seven additional cases since then. Since we have dissected only about sixty cadavers since that time, it is evident that this condition is rather common here. It is possible, though not very probable, that the condition is geographically limited; but one can hardly believe that the occurrence of these

Fig. 2.—Early stage in the destruction of the capsule in a right shoulder joint of a man. The defect in the thickened capsule lies directly above the lesser tuberosity.

cases could be confined to the city of San Francisco, from which we obtained all of our anatomic material. It is true that more arthritic conditions have come to my attention in a single year in our laboratory here, than I saw during four years in other laboratories in which far more dissections were performed; but they seem to fall in a rather different category.

The humerus of each of the six subjects forming the basis of my previous report has been cleaned and bisected longitudinally to permit of inspection of the spongiosa, particularly in the head of the bone.

Although both the humeral tuberosities and the cartilage were partially or wholly destroyed in all these specimens, and although polishing was present somewhere on the head of most of them, the spongiosa contained no gross evidences that there had been suppurative foci previously. This is apparent in Figure 1. Although considerable bone destruction and often also deposition had occurred in the region of the tuberosities of some of these humeri, the underlying spongiosa, nevertheless, was normal. It is true that a large open space is present in the spongiosa under the region of the greater tuberosity in the last two humeri; but as I have previously reported,[2] such not rarely is the case in normal bones. These free spaces in the spongiosa are apparently due to absorption, usually the result of advancing years. Both of the humeri showing these absorption areas came from senile cadavers, and since the adjacent spongiosa looks entirely normal, and since extremely fine trabeculae bridge the margins of these open spaces, it seems very unlikely to me that one could rightly regard them as old abscess cavities from which an infectious process spread to the joints. This conclusion does not, to be sure, wholly exclude the medulla of these bones as a possible source of infection, if such it was, for many of the cancelli are so large that an infectious process, which did not result in destruction of the spongiosa, perhaps could be located there and spread to adjacent extra-articular structures through the numerous vascular canals in the head of the bone. That, however, seems unlikely, although I am not very competent to judge regarding this matter.

Before considering the possible significance of the findings in the seven cases reported herewith, it will be well to examine them somewhat in detail.

DESCRIPTION OF SPECIMENS

SPECIMEN 7.—The earliest stage in the process of destruction of the articular capsule, of the tendon of the long head of the biceps and of the cartilage on portions of the glenoid cavity of the scapula and on the head of the humerus, which I have observed, is represented, in part, in Figure 2. This view represents the lateral surface of the shoulder joint of the right extremity of a male subject and shows the upper end of the humerus and the upper surface of the scapula in outline merely. The border of the opened subdeltoid bursa is represented immediately above the greater tuberosity, and a defect in the thickened articular capsule is shown in natural size directly in front of the acromion. A portion of the articular cartilage on the humeral head is exposed through this defect and very slight bony changes are visible in this portion of the humeral neck.

The biceps is very well developed and the tendon of the long head perfectly preserved up to the region of the tuberosity. It is entirely free throughout the

2. Meyer, A. W.: The Architecture of the Proximal Extremity of the Humerus, Anat. Record **12**:60, 1917.

articulation, and tension on it resulted in movement of the scapula. The superior portion of the capsule of this shoulder joint is from 3.5 to 4 mm. thick and densely fibrous. When the capsule was opened along its inferior border, the cartilage on the head of the humerus and that in the glenoid cavity appeared to be entirely normal. The cartilaginous surface is smooth and glistening and without even a small defect or any evidence of erosion. However, the soft tissues on the inferior surface of the acromion are worn into shreds, apparently from contact with the tuberosities in a position of hyperabduction. The capsular portion of the tendon of the biceps is greatly flattened and shredded, especially on one side, the edges being worn into a fringe for a distance of approximately 4 cm. (Fig. 3).

Specimen 8.—The humeroscapular articulation of the left arm of this female is quite normal. The cartilage is preserved over the whole head of the humerus and also in the glenoid cavity and apparently is of normal thickness. The lesser tuberosity is unaffected, but the greater shows some absorption, roughening, and also some deposition of new bone, especially in the region of the intertubercular sulcus. The capsule is deficient and frayed in its superior portion, and the tendon of the long head of the biceps, which is fused with it,

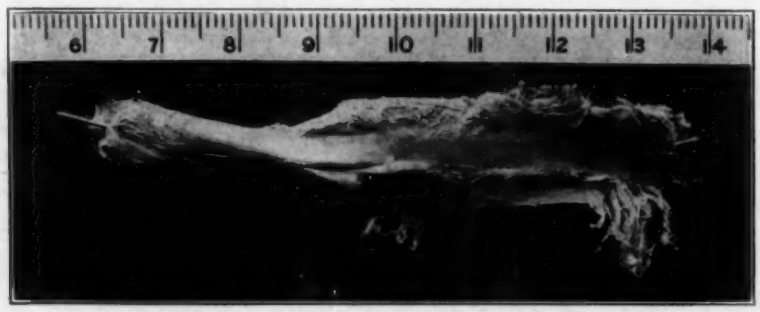

Fig. 3.—Frayed and shredded tendon from Subject 7. The cut scapular end is to the right, and the narrowest part is the intertubercular portion.

is frayed especially along the posterior margin in the region of the tuberosities where it is reached by some remaining strands, only about one fourth the caliber of the normal tendon. The capsule seems thickened in the region of the supraspinatus and the tendon of the latter is firmly fused with it. The fibrous tissue and the periosteum underneath the tip of the acromion are frayed and entirely worn off over small areas on the under surface of the bone. The acromioclavicular joint seems normal, and the same thing applies to the elbow and wrist joints, except that slight erosion of the cartilage is present over a small area of the capitellum.

Since the tendon of the long head of the biceps shows almost complete destruction in this case, and since it also is adherent to the capsule up to the region of the tuberosities, and also because defects are present in the capsule itself and slight bony changes are present on the acromion and tuberosities, one would seem to be justified in concluding that this arm exemplifies a later stage in the process of destruction of the tendon of the long head of the biceps. In fact, this and the previous case are the only ones in which the tendon had not already been anchored in the region of the tuberosities. In the latter region the destruction of the tendon in this case was less evident, while in the former it was almost complete.

SPECIMEN 9.—In this specimen, the left arm of a male, also with splendid muscular development, the tendon of the long head already is anchored to the shaft of the humerus somewhat distal to the tuberosity. The articular capsule is entirely intact except in the region of the lesser tuberosity where it is thin and deficient. The subdeltoid bursa is extensive, and its wall is fused directly with the capsule at the periphery of the deficiency just mentioned. A diverticulum of this bursa extends beneath, and 4 cm. along, the tendon of the short head of the biceps and the coracobrachialis, and also downward for a distance of 3 cm., lying superficial to the tendon of the subscapularis. It is one of the most extensive subdeltoid bursae I have ever seen, and its cavity communicates directly with a humeroscapular articulation in the region of the deficiency above noted.

Considerable destruction of bone is present in the region of the lesser tuberosity over an area of about 7 sq. cm. Deposition of new bone also has occurred, for this atrophic area is studded with half a dozen bony tubercles from 3 to 6 mm. in diameter and 3 to 4 mm. in height. The superior portion of the capsule, containing the tendon of the supraspinatus, is thickened, and the broad attachment of the latter is displaced downward somewhat. A small closed bursa is located within the thickened capsule itself in the region of fusion of the tendon of the infraspinatus. The cartilage of the humerus is well preserved and appears quite normal, but numerous villi, many of which seem frayed, are located on the under surface of the capsule near its attachment to the superior border of the glenoid cavity. The articular capsule is thickened and fenestrated in its anterior portion near its attachment to the shaft of the humerus directly below the lesser tuberosity. The attachment of the tendon of the long head of the biceps directly distal to the tuberosities is very firm and no remnant of the intra-articular portion could be identified with the unaided eye in cross-sections of the capsule. The cubital, carpal, and the more distal articulations are normal, but the acromioclavicular articulation showed marked bony changes. Both the acromial and clavicular articular surfaces are decidedly roughened and eroded and the cartilage completely destroyed, although the polishing of the acromion is relatively slight.

SPECIMEN 10.—A stage similar to that reported in the preceding specimen is found in the right arm of the same male cadaver, in which all other articulations appear to be normal. In this case also the tendon of the long head of the biceps has secured a firm attachment directly distal to the lesser tuberosity. This attachment is quite comparable to that in the preceding case, and the defects in the capsule also are similar, although somewhat more extensive. The subdeltoid bursa is not so large but the deficiency in the capsule corresponds to more than the anterosuperior half of the head of the humerus. The borders of the capsular defect are thickened, and the dorsal portion receives the displaced tendon of the supraspinatus which has fused firmly with the tendon of the infraspinatus, maintaining however, an attachment to the greater tuberosity although displaced somewhat dorsally. The inferior surface of the acromion shows considerable superficial erosion, which is limited, however, to fraying of the soft tissues. A group of synovial villi is present in the subacromial portion of the subdeltoid bursa, and similar villi also are present on the paraglenoid portion of the articular capsule. The other articulations appear entirely normal and the bony changes seem to be limited to the region of the lesser tuberosity and the intertubercular sulcus. The long head of the biceps is surrounded by the nonadherent synovial sheath for a distance of 5 cm. distal to the tuberosities. This maintains its connection with the joint cavity.

Specimen 11.—This is the left arm of a male subject in which the tendon of the long head of the biceps again is attached immediately distal to the lesser tuberosity as shown in Figure 5. The capsule is deficient in its whole superior extent, its thickened, retracted, dorsal borders containing what seems to be a remnant of the intertubercular portion of the tendon of the long head of the

Fig. 4.—Left arm of a male subject from the front, showing the secondary attachment of the tendon of the long head, the retracted capsule with the tendon of the subscapularis and complete destruction of the superior portion of the capsule. The unusual length of the tendon of the long bicipital head may be noted.

biceps. The thickened portion of the joint capsule is markedly frayed in the region of the greater tuberosity, which is eroded and polished over an area of about 4 sq. cm. As shown in Figure 5, the retracted, thickened anterior portion

of the capsule containing the tendon of the subscapularis has been displaced downward below the level of the head of the humerus. The greater portion of the lesser tuberosity has been destroyed, it being represented by a roughened area to the anterior inferior margin of which the tendon of the subscapularis finds its attachment. The cartilage on the midportion of the humeral head is roughened and almost wholly eroded, but no equivalent area is seen in the glenoid cavity. However, the cartilage is completely eroded near the posterior superior margin of the glenoid cavity and here the underlying bone is polished. This narrow eroded area also extends along the anterior border of the glenoid cavity,

Fig. 5.—Right shoulder joint with the deltoid cut and reflected, showing the point of secondary attachment of the tendon of the long head, the partly occluded intertubercular sulcus and a third head of the biceps obtaining attachment to the tendon of the pectoralis major. Two-thirds natural size.

and inspection of the entire articulation shows that it was contact with this margin that caused the erosion of the cartilage at the most prominent portion of the humeral head. The under surface of the acromion is worn and polished over almost its entire extent, apparently in consequence of contact with a similar, although smaller, area on the greater tuberosity, during a position of extreme abduction. The rest of the joints are normal.

SPECIMEN 12.—A more advanced stage is illustrated by the right arm of a similar subject, a portion of which is represented in Figure 5. As will be noticed, the deltoid has been reflected, and the entire joint cavity has been

laid open. The tendon of the long head of the biceps is attached directly distal to the lesser tuberosity and a third head gains insertion into the tendon of the pectoralis major. The greater tuberosity is considerably eroded and decidedly polished. The under surface of the deltoid is frayed near its acromial attachment as a result of contact with the greater tuberosity. The under surface of the acromion is worn and polished so as to fit exactly a similar area on the greater tuberosity when the arm is placed in a position of hyperabduction and outward rotation. The acromioclavicular ligament and the inferior surface of the capsule of the acromioclavicular joint are entirely destroyed and small areas of the exposed articular surfaces are polished from contact with the head of the humerus and with each other. The capsule of the shoulder joint is destroyed almost completely, only the thickened margin remaining along the anterior border between the region of the coracoid and the acromion. Except for the margin in the region of the tuberosity, the cartilage is present over the entire humeral head and appears quite normal in depth, thickness, and consistency, both over the head of the humerus and in the glenoid cavity.

SPECIMEN 13.—This is represented by the right arm of a male subject and illustrates a still more advanced stage of this condition. As shown in Figure 6, the cartilage over the head of the humerus is very largely eroded; large polished areas are present, and the tuberosities are almost wholly destroyed. The under surface of the acromion again is worn and polished and calcific deposits are present in various portions of the capsule and in the coraco-acromial ligaments. In this case, too, the deltoid acted as the capsule of the joint, and the acromioclavicular joint was laid open in consequence of wear from contact with the greater tuberosity. Almost the entire margin of the glenoid cavity is eroded, but cartilage is present over the rest of the surface. A remnant of the missing tendon of the long head of the biceps possibly may be detected still in the thickened retracted portion of the capsule which hoods the upper half of the glenoid cavity. This remnant of the capsule is interposed between the glenoid cavity and the head of the humerus, which had been elevated against the acromion.

COMMENT

That the disappearance of the tendon in these cases is not due to disuse is fully established by an examination of the same tendons in a case of congenital hydrocephalus in a woman more than 40 years of age. This woman had been partly paralyzed from birth, and although fibrous ankylosis had supervened in the right humeroscapular articulation, thus practically immobilizing this joint, and although the tendon of the biceps was atrophic, it nevertheless could be traced in its entirety although adherent to the joint capsule. It is interesting that it was more difficult to trace this tendon in the left than in the right shoulder joint of this body, although fibrous ankylosis was absent in the latter in which complete erosion of the articular cartilages had taken place and the whole interior surface of the dorsal and inferior portions of the capsule were covered by numerous long and large synovial villi. Except for the complete erosion of the articular cartilages in this joint and the excellent polishing present over the whole of the articular

surfaces, the entire picture was totally different in these two joints from that in those with destruction of the long head of the biceps.

Although erosion, polishing, some eburnation and small exostoses are commonly present in cases of arthritis, these are not the most prominent conditions in the specimens here reported. Next to destruction of the tendon of the long head of the biceps with secondary attachment of the tendon stump distal to the lesser tuberosities, nothing strikes

Fig. 6.—Lateral view of right shoulder joint of a male. This shows the most advanced stage of destruction. The deltoid acted as capsule to the joint.

one's attention so forcibly as its total destruction by friction. That friction is very largely if not wholly responsible is indicated by the fraying and fringing of the other soft parts and also by fraying and shredding of the tendon itself. It is surprising and extremely significant that destruction of the tendon can reach a considerable degree in a shoulder joint with cartilages wholly intact and with but a small capsular defect, at a time when the tendon is almost wholly free from adhesion to the capsule.

The first defects in the capsule occur in the region of the tuberosities, and erosion of its external surface often is present in this region alone, although corresponding wear is evident in the soft parts on the inferior surface of the acromion. Since the eroded and polished areas always fit exactly when placed in contact, one cannot doubt that the erosion occurs in a position of marked abduction and external rotation of the arm. This also is the only position in which the under surface of the deltoid in the region of the acromion could become frayed from contact with the greater humeral tuberosity. That the capsular defects always are more pronounced in the region of the latter, even when not wholly confined to it, and that they seem to begin here may be due to folding of the capsule and friction from contact of the greater tuberosity with the acromion, in a position of marked abduction and external rotation of the arm.

Whatever the associated conditions may be, it would seem that these capsular defects result from repeated and long-continued use of the arm in a position of marked abduction and external rotation. This is indicated especially by the antecedent fraying of the soft tissues on the under surface of the acromion with accompanying abrasion in the region of the tuberosities. It would also seem that the irritation and trauma resulting from this friction might bring on a subdeltoid bursitis antecedent to the destruction of this bursa. This unavoidable trauma to the soft parts undoubtedly would also be followed by a protective reaction in the superior portion of the capsule and thus cause thickening of it. However, as soon as the capsule has been worn through near the region of the greater tuberosity, the rough surface of the latter can come in contact with the capsular portion of the tendon of the long head of the biceps and begin its erosion and final destruction.

Although the supposed course of events is merely an inference from the findings in these cases, it quite satisfactorily accounts for all the changes observed, profound though they are. It also accounts for the fact that the pathologic picture in these cases is not wholly comparable to that usually presented in arthritis. The new bone formation, present to some extent in most of these cases, in the region of the tuberosities and in the intertubercular sulcus, may be merely the result of traumatic irritation of the periosteum. Likewise the inflammatory reaction evoked here and in the adjacent soft parts may be responsible for the invariable anchoring of the divided tendon in the region directly distal to the lesser tuberosity.

When the extracapsular lengths of the remaining tendons in cases in which the intracapsular portion was absent were compared with normal tendons, the greater length of the former was very evident. This is noticeable in Figure 4. This increase in length of the tendon between

the muscular portion of the long head and its attachment to the lesser tuberosity may be due in part to atrophy of the muscular belly, but I do not think that this is an important factor. It would seem more probable that the increased length of the extracapsular portion of the tendon is due to retraction in consequence of division near its scapular insertion. However, since this portion of the destroyed tendon not always is longer than the corresponding portion of the normal tendon, it would seem that the tendon sometimes gains attachment in the region of the tuberosity before it is divided, thus limiting the extent of the retraction. This attachment well may result from trauma of the soft parts in this region in consequence of contact with the acromion.

I have not, to be sure, overlooked the possibility of cases of partial congenital absence of the tendon of the long head. Although I have

Fig. 7.—The thickened, trabeculated interbursal septum from the pateliar bursae.

seen but two such cases, they gave me a totally different impression, and I think they may be easily excluded.

The uniformity and the very apparent significance of these findings led me to consider the possibility of an occupational cause, although at first the destruction seemed too extensive to permit of such an assumption. It always had seemed to me that whatever the process responsible for this extensive destruction of the bursa, capsule, tendon and cartilage, it was extra-articular rather than intra-articular. It was because of this fact that I placed an interrogation point in the title of my previous report. The condition did not seem to be primarily arthritic.

It seems possible that long-continued use of the upper extremity in such a posture might easily result in a subdeltoid bursitis, an extension of which to the articulation itself after the production of friction defects in the capsule, easily might complicate the picture; but the arthritic changes always seemed to be of secondary importance. The entire

absence of any evidence of pathologic changes in the spongiosa of the humeri in the first six cases also encouraged me to continue to look for an extra-articular cause. Since the soft tissues on the under surface of the acromion were frayed in many of the cases in which the region of the greater tuberosity also showed slight wear although the capsule and the tendon were wholly preserved, it seemed quite evident that the destructive agent must be friction from contact of the greater tuberosity with the acromion. This was illustrated very well by cases in which this friction had resulted only in slight fraying of the surtaces of contact—the greater tuberosity and the acromion—all else being normal.

Fig. 8.—Subcutaneous and subfascial bursae in the region of the right olecranon, the eroded surface of which forms the base of the deeper bursa. The thickened, cut, reflected trabeculae, especially on the internal surface of the left wall of the superficial bursa, may be noted.

It is somewhat surprising, to be sure, that the thirteen specimens at hand were divided almost equally between right and left arms, for an occupational condition affecting the arms might be expected to affect them approximately in the ratio of right and left handedness. This would cease to be true, however, in all occupations in which no particular skill in the use of the arm is involved, so that the worker could turn from one to the other arm with almost equal facility. Both tendons were destroyed in only one person, and since the arms of two females are included it would seem that several occupations are involved.

I regret exceedingly that it is not possible to verify my explanation from the histories of these cases; but the facts are so unequivocal that I no longer can doubt that the cause of this destruction really is an occupational one.

One might perhaps expect that repair of the tendon would occur or even that such constant use of the arm might result in its hypertrophy. It must be remembered, however, that the posture in which the arm is placed in these movements is rather an abnormal one and that the tendon itself is not subjected to unusual strains but to direct friction from contact with a rather roughened surface which is wholly avoided in the more usual movements of the arm. In a position of extreme abduction and outward rotation, neither tendon nor capsule nor bursa could be expected to show much resistance. Moreover, it is not at all unlikely that tendons have very little regenerative power. This probably would be true especially of such tendons as that of the long head of the biceps which undoubtedly has a relatively poor blood supply. Since none of the twelve shoulders in which the tendon had been destroyed completely contained abrasion products, these apparently are absorbed. I am at a loss to know what the digestive agent is; but the problem is no greater than in cases of abrasion products in connection with erosion of the articular cartilages.

The destruction of the subdeltoid bursa and the joint capsule in these cases reminds one strongly of cases of "housemaid's knee" and "miner's elbow," in which the dense fascial wall between the subcutaneous and subfascial bursae not rarely are shredded from wear, as represented in Figure 6, a photograph of the intervening septum from the patellar region. This septum often is thickened decidedly as well as completely fenestrated, or even trabeculated, and it does not seem improbable that it might ultimately be destroyed completely.

There usually is only one subcutaneous bursa in the region of the olecranon. Rarely, however, two bursae, a superficial and a deep, are located here, wholly comparable to those usually present in the patellar region. The wall of the superficial bursa over the olecranon invariably is thickened when a subfascial bursa is present. This is particularly true of the interbursal septum since the deep fascia over the olecranon is relatively thin. It is evident that long continued use apparently results in extraordinary thickening of it, for it not rarely is 3 mm. thick. In two instances recently observed, these thick interbursal septums, which very evidently must have developed from the deep fascia in response to use, had become fenestrated and were densely fibrous, almost cartilaginous in character. Trabeculae of dense connective tissue also were contained on the inner surface of the bursal walls and in both these cases the olecranon was devoid of periosteum over its

most prominent portion, hence a part of the base of the deeper bursa was formed by bare bone. The size of these bursae alone indicates that there must have been considerable irritation and effusion; but it seems rather surprising that overuse, which results in thickening of the walls, the formation of a deeper bursa and greater thickening of the interbursal septum, also may result in destruction of the septum of the periosteum and erosion of the underlying bone. In both these cases fenestrae and trabeculae were found in the thickened wall between the two bursae, and the condition here was entirely comparable to what one not infrequently finds in the patellar region.

RECURRENCE OF CALCULI IN COMMON AND HEPATIC DUCTS AFTER CHOLECYSTECTOMY *

GEORGE EMERSON BREWER, M.D.
NEW YORK

When one is invited to read an article or to present some topic of professional interest before a medical society, the choice of a subject is often dependent to some extent on the character of the audience. Thus, if one wishes to announce some new or epoch-making discovery, to place on record some valuable, but hitherto unknown, therapeutic measure, to describe some novel and highly successful operation or surgical procedure for the relief or cure of some malady which had hitherto been regarded as hopeless, one is apt to select a large gathering of his professional colleagues, such as one of the great national associations or international congresses, so that the benefit of his discovery or clinical experience may quickly reach the largest number of his professional brethren and through them promptly be handed on to suffering humanity. If, on the other hand, one is anxious to obtain enlightenment on some knotty clinical problem, or seeks to learn from the experience of others how some failure or mistake may be avoided in the future, he generally seeks a smaller body, made up of men whose experience has been greater than his own and in whose judgment and skill he has confidence.

On the only other occasion that I was privileged to address this society, I presented a report on a small, but interesting, group of cases of hemolytic jaundice, in the hope that I might learn from the discussion something more in regard to the nature of this unusual pathologic condition than I had been able to glean from a rather hasty and incomplete review of the literature.

The result in that instance was so satisfactory that I have elected, this evening, to present another group of cases in which jaundice of another and commoner type is one of the chief factors; and I am looking forward with confidence to obtaining from your discussion helpful suggestions which will be of service to me in any future cases I may encounter.

During the last twenty-five years, I have had under my care for operative treatment five cases of obstructive jaundice due to calculus in the common or hepatic ducts, in which previous operative procedures

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for cholelithiasis had been carried out, including removal of the gallbladder.

That cases belonging to this group are rare is evidenced by the scanty references to them in the standard treatises on diseases of the biliary passages; and by the fact that in several recent communications on the subject of recurrences, by Deaver, Judd and others, the small number of recurrences of stone in the duct after cholecystectomy is in striking contrast to the larger number following cholecystostomy.

REPORT OF CASES

Case 1.—A woman, aged 60, had submitted to an operation for cholelithiasis performed by one of America's most distinguished surgeons. The gallbladder containing calculi was removed. My meager records do not state whether or not the duct was opened at that time; but from my knowledge of the wisdom, judgment and skill of the operator, I am satisfied that the palpable ducts were free from calculi at the time of operation.

Nine months later, the patient consulted me, complaining of intermittent attacks of pain and slight jaundice. The duct area was exposed, the common and hepatic ducts were found moderately dilated, but showed no other pathologic condition, and were palpated with a negative result. The common duct was opened by a longitudinal incision and a probe was passed easily and without obstruction to the duodenum. The hepatic ducts were next explored; and in the right duct, about three-quarters inch above its entrance into the liver substance, the probe touched a calculus. Attempts to remove the calculus by means of curved forceps were unsuccessful as the blades could not be opened sufficiently wide through the narrow duct to grasp the stone. Then followed a slow and careful dilation of the duct by forceps and the finger, which, much to my surprise, was accomplished without difficulty. When I was finally able to insert my forefinger and touch the calculus, it was found to occupy a dilated pouch fully as large as an English walnut. After further forcible dilation and rupture or incision of the duct, I was able to extract the largest stone I have ever encountered in the duct system of a patient. It measured more than 3 cm. in its greatest diameter, was irregularly cuboidal in shape, black, and when thoroughly dried was exceedingly light in weight and resembled pumice stone in structure: a typical bilirubin-calcium stone, which forms only in the ducts. Drainage by means of a rubber tube was introduced to the intrahepatic pouch, and the patient made an uninterrupted recovery.

Two years later she reported that she was well, never having suffered from a recurrence of symptoms.

Case 2.—A married woman, aged 50, referred to me by the late Dr. Roswell Park of Buffalo, gave a history of recurrent attacks of colic of the upper abdomen without jaundice, of many years' duration. During the last two or three years, in addition to the colic, there had been associated symptoms of infection, with tenderness and muscular rigidity over the gallbladder area. At operation, shortly after one of these attacks of cholecystitis, the gallbladder was found to be injected, moderately distended, thickened and edematous; and through its walls could be palpated a number of stones, the largest being impacted in the ampulla at the origin of the cystic duct. The gallbladder was removed unopened, the ducts palpated, and as no sign of calculus, dilatation,

or other lesion was demonstrated, the wound was closed with a small cigaret drain. She made a prompt recovery and remained free from symptoms for more than two years.

Then she began to have attacks of epigastric pain with transitory jaundice, but without fever or other evidences of infection. In November, 1911, she was again admitted to the hospital, and at operation the common duct was found to be greatly dilated and a large, round calculus was easily palpated in its lower segment. The common duct was freely opened, the stone extracted, and the ducts easily explored by the finger and probe well within the liver to the point of branching. Drainage of the hepatic duct by means of a rubber tube was instituted, and the abdominal wound was closed by layer suture. Drainage was continued until the bile appeared clear and golden brown, when the tube was removed and the wound allowed to close. The calculus in this instance was oval, black, nonfaceted, with a mulberry surface. It measured 1.5 by 1 cm. in its two diameters. It was of the type of single stone frequently found in the duct, and at the time I was convinced that it had originated in the duct system after my previous operation.

CASE 3.—A married woman, aged 60, in March, 1911, underwent an operation in Brooklyn for cholelithiasis, which consisted in opening the gallbladder, removing the stones and closing the wound with drainage. This was followed by recurrent abscesses, and a sinus which persisted for many months.

In October, 1912, cholecystectomy, with removal of stones from the common duct was performed by Dr. Hartley. The patient remained well for eighteen months, when there was a recurrence of symptoms: colic and intermittent jaundice at first, later progressive icterus with clay-colored stools, intense itching, fever, and rapid loss of flesh and strength.

She was admitted to my service at the Roosevelt Hospital with a temperature of 101 F. At operation, the duct was found to be widely dilated; several large, dark brown stones were removed, and the common and hepatic ducts were explored with the finger and probe from the duodenal orifice to points in both hepatic branches well within the liver substance. Tube drainage of the duct was instituted. Normal convalescence followed, with complete disappearance of symptoms and rapid gain in weight. She remained well for eight months.

There then occurred dull pains in the epigastrium of short duration; on one occasion extending to the back and right scapular region. This, however, caused little inconvenience until the latter part of 1915, when she had a series of attacks of sharp colic with transitory jaundice, finally eventuating in a severe attack with chills, fever, and a rapidly deepening icterus. She delayed operation for some weeks in the hope of spontaneous relief, but was finally admitted to my service at the Presbyterian Hospital. In January, 1916, she was again anesthetized and a fourth operation was performed. Owing to the presence of dense adhesions over the entire upper abdominal area, the technical difficulties were considerable. I finally succeeded in exposing the common duct which was greatly dilated, resembling a misplaced gallbladder. This was incised and a large amount of dark brown, foul-smelling fluid evacuated, together with seven soft, brown gallstones, three of which were found high up in the hepatic ducts, well within the liver. Digital palpation of the ducts was followed by irrigation, and the insertion of a rubber drainage tube in the hepatic duct. Drainage was continued for several weeks. She made a slow but satisfactory convalescence. Cultures made at the time of operation gave a gram-positive bacillus. Later cultures showed a colon infection. From the odor of the duct secretion at the time of operation, it is probable that *B. coli*

was present from the first. Autogenous vaccines were made from the cultures and administered for several weeks after she left the hospital by Dr. George Draper, who was called in to study the case and prescribe measures to prevent a recurrence.[1]

Case 4.—A middle-aged man had been operated on by the late Dr. O. C. Smith of Hartford for a series of attacks characterized by colic, jaundice, chills and fever. The gallbladder was removed and the ducts explored. The patient remained well for twenty months, when there was a recurrence of symptoms, with pain, jaundice, fever and clay-colored stools. These symptoms promptly disappeared; and one year later, he experienced another similar attack which also disappeared without treatment. Six months before admission to the Presbyterian Hospital he began to have frequent mild attacks with jaundice, which never completely disappeared. At operation the duct was found moderately dilated, but palpation revealed no foreign body. The duct was opened and explored with the finger and probe with a negative result. The hepatic ducts within the liver were irrigated with a small catheter, and eight or ten small faceted, yellow stones were washed out from a point high up within the liver substance. Drainage of the hepatic duct was instituted, and the abdominal wound closed in the usual manner. Prompt recovery followed. A letter received four years later stated that he had experienced no return of symptoms.

Case 5.—A woman, aged 64, consulted me in March, 1915. There was a history of attacks of acute abdominal pain of many years' duration. At first these, thought to be due to indigestion, were apparently of short duration and were relieved by catharsis. Later the attacks became more severe, required more or less prolonged rest in bed, and at times were accompanied by a transitory jaundice.

The present attack began six days before my first visit, with severe abdominal pain, tenderness, nausea, vomiting, fever and increasing prostration. On examination, the abdomen was found to be distended. There was generalized tenderness and marked muscular spasm over the right half. The point of most acute tenderness was midway between the appendix and the gallbladder areas. The temperature was 103.5 F.; the pulse, 120. She was immediately removed to the Roosevelt Hospital, and at operation a gangrenous, ruptured appendix was found with spreading peritonitis. The gallbladder region was not explored; and as her condition was critical, after the removal of the appendix, the abdomen was quickly sutured with adequate drainage. The operation was followed by a stormy convalescence with long-continued drainage. Six weeks later, after the abdominal wound had closed, but before she had left her bed,

1. Since this was written, I have received a communication stating that this patient remained well for eighteen months after my last operation. She then had a renewal of attacks, and was operated on for the fifth time by a colleague, and two or three stones were removed from the duct. She apparently remained well for about a year. During the summer of 1919, she began taking probilin pills—a phenolphthalein-containing nostrum—and on the third day she had another attack of acute abdominal pain exactly similar to those she had had in the past. The pills were omitted and the attack subsided. Later the pills were again resumed, and another attack occurred. She then had a roentgenologic examination made of her teeth, and as a result of the findings, had nine teeth extracted in November last. She has had no attacks since that time.

there occurred another attack of acute epigastric pain with nausea and vomiting, followed by fever and jaundice on the second day. As the symptoms were progressive, a second operation was undertaken. The gallbladder was acutely red, edematous and covered with fibrin. On palpation, numerous large and small stones were felt within its cavity. The common duct was dilated and one large oval calculus was palpated in its lower segment. The gallbladder was removed, the common duct incised, and one large and two small calculi were removed. The ducts were thoroughly explored with the finger and probe, and the incision was partly sutured with drainage of the hepatic duct. The following day the temperature reached 101 F., and from that time gradually fell to normal. The convalescence was rapid and satisfactory, and she left the hospital in excellent condition.

She remained well for four years, ate heartily, gained weight, and considered herself thoroughly cured. In the summer of 1919, however, she again began to experience attacks of epigastric pain of short duration, occurring at irregular intervals, but relieved by rest and mild catharsis. In September, I was again called in consultation during one of these attacks. On examination, I found tenderness with slight muscular spasm in the epigastric region, and slight but definite jaundice and no fever. I urged her to enter the hospital again for further observation. This she refused. The attacks continued, gradually increasing in severity, and requiring increasing doses of morphin for their relief. Three weeks later, I saw her again and gave the same advice, but she again refused to enter the hospital. Three months later, I was again called, and found that her condition was much worse. She had just passed through a severe attack requiring much morphin, and the condition was complicated by definite evidences of impaired renal function.

She was finally admitted to the hospital, and on examination the blood pressure was found to be 95-55. The urinary output on the first day was 12 ounces, and on the succeeding day 20. The urine contained albumin and casts. Blood examination revealed: nonprotein nitrogen, 97.50; urea nitrogen, 50.40; creatinin, 2.30; uric acid, 3.40; sugar, 0.098, and carbon dioxid, 60.30. The blood coagulation time was fourteen minutes. She was given water in large quantities, restricted diet, and hot air baths. For several days she was somewhat apathetic, complained of headache, nausea, and occasionally she vomited. The jaundice diminished, but never entirely disappeared. The urine gradually increased to 40 ounces during the following week, and January 9, the report showed nonprotein nitrogen, 47.80; urea nitrogen, 25; creatinin, 1.60; uric acid. 3, and sugar, 0.08. The following two days the amount of urine collected was 18 and 17 ounces, respectively. She then experienced another severe attack of pain, with nausea, vomiting, fever and increased jaundice. The pain was very severe, but as we dared not give her morphin, after consultation we decided to take a desperate chance and operate.

Every effort was made to insure speed of operation, but the adhesions were very extensive, and were separated with great difficulty. The duct was finally exposed. It was found to be much dilated, a stone was palpated and removed through a longitudinal incision. The ducts were thoroughly explored without detecting other calculi. Drainage of the hepatic duct was instituted. The operative shock was not grave; but the day following there was a total suppression of urine, only 2 drams being recovered by catheter. On the second day, the output was half an ounce, and on succeeding days it was 1½, 2, 17, 25, 22, 20½ and 27 ounces. During this period, she was having colon irrigations, cupping, hot packs, intravenous infusions, digitalis, and various other

renal stimulants. There was little postoperative abdominal discomfort. The drainage was abundant. Gas passed freely on the second day, and the bowels moved satisfactorily on the fourth. Sutures were removed on the seventh day. On the ninth day, following the voiding of 27 ounces of urine, she had an attack of cardiac weakness, the excretion of urine ceased entirely, and she died in coma.

The outcome in this case was disappointing as the wound had healed, the drainage tube having been removed two days before, and bile was abundantly present in the stools. It was not, however, unexpected, as I had explained to her family that she had a slight chance of recovery, which would be reduced to zero if the operation was long, more than forty minutes. The actual time of operation, in spite of all our efforts to accelerate it, was more than an hour. It may be that the decision to operate when we did was unwise but to attempt to carry her through another severe attack with the necessary relief from pain by morphin seemed at the time to be hopeless.

COMMENT

It may fairly be assumed that in Case 1 the calculus was probably present in the duct from the beginning, and did not form around an overlooked stone which had migrated to the duct from the gallbladder.

In the second case, the absence of jaundice prior to the first operation, the normal appearance of the duct, and the absence of any evidence of calculus by careful palpation, together with the comparative long interval which elapsed before the second group of symptoms appeared, and the fact that the stone was round, nonfaceted, black and soft, a typical bilirubin-calcium stone, would lead one to regard it as a concretion formed in the duct. On the other hand, these stones are exceedingly rare in uninfected ducts, and the origin of this calculus must be regarded as uncertain.

In Case 3, the duct had already contained one or more calculi, and was therefore presumably infected, conditions favorable for the subsequent formation of duct stones. While it is quite possible that stones hidden in one of the hepatic branches might have been overlooked in any or all of the operations, it is equally possible that the stones formed in the duct between operations, as all conditions favoring calculus formation were present, and as the ducts were widely dilated and easily permitted careful digital exploration.

In Case 4, the character of the stones and their lodgment in the intrahepatic ducts strongly suggest their duct origin. In fact, Beer reports a case in which at necropsy he found a number of small, yellow, faceted stones embedded in one of the smaller intrahepatic ducts, exactly similar to those removed in this case.

In the last case, it is quite probable that a stone might have been overlooked at the second operation, as the condition of the patient at operation was such as to render the expenditure of much time inad-

visable; but the four years of entire freedom from symptoms would make one hesitate to affirm it.

It is perhaps unfortunate that no sections were made of any of the stones removed from the ducts in this series of cases and examined chemically, for the result of such investigation might have thrown some light on their probable origin.

It is now generally recognized that stones formed in the gallbladder generally contain a high percentage of cholesterin, in most cases combined with bilirubin and biliverdin calcium compounds; that they are polished, faceted, and that they vary in color from a light gray or yellow to dark brown or black; the pure cholesterin, the laminated cholesterin or the typical bilirubin-calcium stones being comparatively rare.

On the other hand, calculi formed in the ducts are almost invariably of the bilirubin-calcium type, containing a low percentage of cholesterin; are rarely polished or faceted, and are irregular in shape, black and friable. One of the rarest varieties of duct stone is the small yellow faceted stone formed in the smaller intrahepatic ducts, often in considerable numbers, as in Case 4 and in the case mentioned by Beer.

The finding of a typical gallbladder stone in the duct, or an irregularly shaped, black, friable stone, with a nucleus showing the characteristics of a typical cholesterin stone, would indicate that the duct exploration at the primary operation had been incomplete; as after removal of the gallbladder, no such stone could have migrated to the duct or could have had its origin in the duct system.

If, on the other hand, the examination of the stone demonstrated it to be of the bilirubin-calcium variety, it would by no means prove that it, also, was not an overlooked stone, as such stones of intrahepatic origin are not uncommon in infected ducts which have been dilated by the previous presence of calculi.

It is, therefore, quite useless to speculate further on the question as to the exact origin of these stones, and to admit freely that in three of the cases it is quite possible that the stones removed may have been formed around overlooked stones or fragments present in the duct at the primary operation.

The important question is, what can be done to avoid recurrences in this class of cases?

Unquestionably, early operation, so often emphasized by Deaver and other surgeons of large experience, is highly important, as practically all biliary calculi, with the possible exception of the so-called pure crystalline cholesterin stone, are due primarly to infection. Surgical removal, therefore, at an early period, before advanced or permanent inflammatory changes have occurred in the gallbladder and ducts,

is to be recommended. Thoroughness in exploration of the ducts with the finger, probe, and by irrigation at the time of the primary operation, is also of prime importance, for I believe we will all admit that a very large number, if not the majority, of duct recurrences, are due to the presence of overlooked stones or fragments.

It must be recognized, however, that even the most thorough search of the biliary passages by the most skilled operator may fail to reveal the presence of calculi lodged in a small branch of the duct system in the liver substance. Moreover, a floating stone once palpated in the unopened common duct may be aspirated or forced upward into the liver ducts by digital pressure. If the duodenal orifice of the duct is obstructed, the suggestion of Gerster, that in such cases the duct should be palpated only after it has been incised, is a logical one. Equally important in my opinion is prolonged and free drainage of the duct after operation. This, as in other infected cavities, removes pressure, allows the free escape of infected fluid, and favors Nature's process of repair, which in the last analysis is the one most important factor in recovering from any infection.

THE RÔLE OF THE URETERAL LYMPHATICS IN EXPERIMENTAL URINARY TRACT INFECTIONS *

VERNON C. DAVID, M.D., AND PETER M. MATTILL, M.D.
CHICAGO

In a previous article [1] the results of an experimental study to determine the routes by which infection could ascend from the bladder and involve the upper urinary tract were published. In that article these statements were made:

1. In experimental *B. coli* cystitis in dogs, blood stream infection rarely takes place.

2. Without stasis of urine, involvement of the upper urinary tract is rare.

3. With slight obstruction to complete emptying of the bladder, extension of infection to the upper urinary tract practically always occurs.

4. The involvement of the upper urinary tract almost uniformly takes place through the lumen of the ureter, and the ureteral lymphatics are rarely, if ever, the pathway of infection.

Since some of these statements are at variance with the reports of other workers on the same, or correlated, subjects, further evidence will be presented bearing on the rôle of the ureteral lymphatics as a pathway for infection involving the urinary tract.

URETERAL LYMPHATICS AS A PATHWAY FOR INFECTION WITHIN THE URINARY TRACT

Eisendrath and Schultz [2] described round-cell infiltration in the ureteral lymphatics after injecting *B. coli* into the bladder. Bauereisen [3] described the same findings in tuberculosis of the bladder. Stewart [4] explained the kidney infections following implantation of

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* From the Surgical Department, Rush Medical College, and the Otho S. A. Sprague Memorial Institute, Children's Memorial Hospital.

1. David, Vernon: Ascending Urinary Infections, Surg., Gynec. & Obst. **26**:159 (Feb.) 1918.

2. Eisendrath and Schultz: The Path of Involvement in Ascending Infections of the Urinary Tract, J. M. Research **35**:295, 1917.

3. Bauereisen, A.: Beitrag zur Frage der aszendierenden Nierentuberkulose, Ztschr. f. gynäk. Urol. **2**:132, 1910.

4. Stewart, L. F.: A Study of Ascending Infection of the Kidney Carried Out by the Transplantation of the Ureters Into the Intestines, Univ. of Penn. M. Bull. **23**:233, 1910-1911.

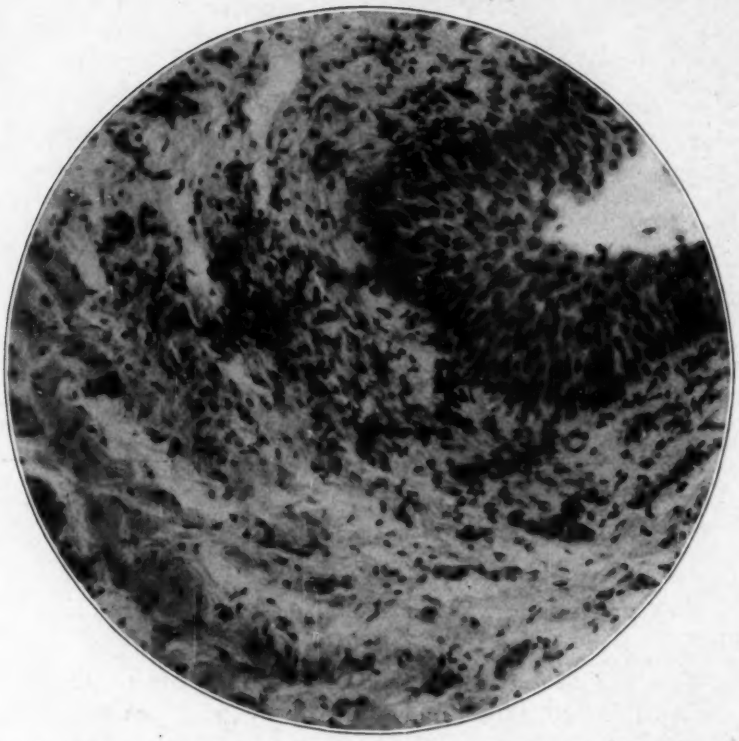

Fig. 1.—Round-cell infiltration in submucosa of ureter of control dog with sterile urine; × 230.

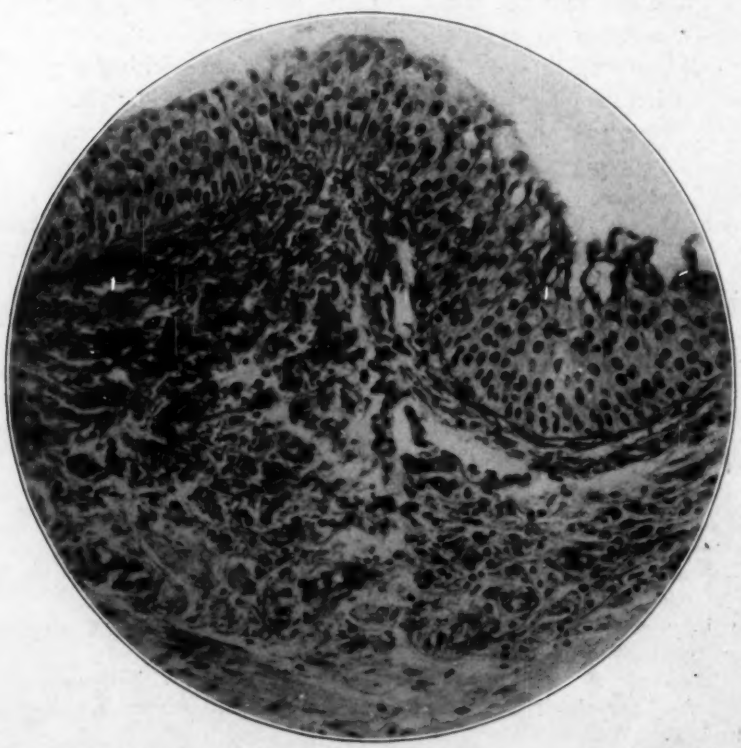

Fig. 2.—Round-cell infiltration in submucosa of ureter of control dog with sterile urine; × 230.

the ureters into the intestinal tract on the basis of an ascending infection through the lymphatics of the ureter. Franke [5] injected lymphatics running from the cecum and ascending colon to the kidney capsule and kidney pelvis. Helmholz and Beeler [6] injected cultures of a virulent organism, found in a rabbit kidney, into the bladders of a series of rabbits. They found pyelitis in fifteen of the animals, but there was evidence of cellular exudate in the ureteral lymphatics in only five. They concluded from this evidence that in some instances

Fig. 3.—Round-cell infiltration of the submucosa of the ureter; sterile cultures from the lumen of the ureter as well as from the macerated ureter; ×60.

the infection ascended by way of the ureteral lymphatics and in others through the lumen of the ureters. In another series of experiments on sixty-six rabbits, organisms of the *B. coli* group were injected intravenously, and pyelitis was found in only two animals. In some

5. Franke: Aetiologie der Coli-Infektionen, Arch. f. Anat. u. Physiol., 1910, p. 191, Ueber die Coliinfektionen der Harnwege, Berl. klin. Wchnschr. **48:** 1973, 1911.

6. Helmholz and Beeler: Infection of the Urinary Tract, Tr. Am. Pediat. Soc. **30:**195, 1918.

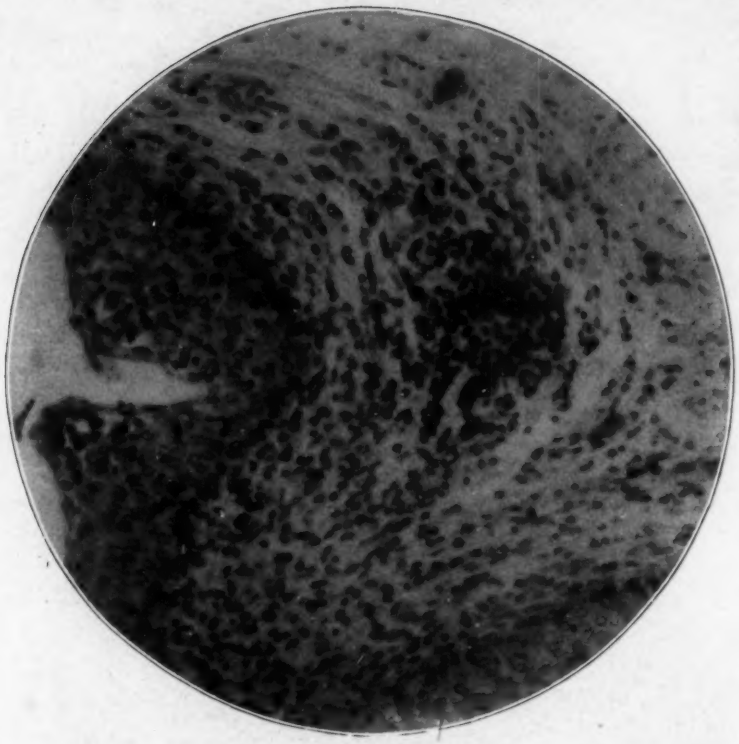

Fig. 4.—Round-cell character of infiltrate shown in Figure 3; ×230.

Fig. 5.—Bladder submucosa with polymorphonuclear infiltrate; ×130.

of the experiments a polymorphonuclear exudate was found in the subpelvic lymphatics.

Elaborate studies of the lymphatics of the bladder, ureters and kidney have been made by injection of the lymphatics with silver salts and Prussian blue (Mascagni, Teichman, Sappey, Krause, Gerota, Kumita, Stahr, Sakata). There is no doubt that a rather rich lymphatic system is found in the submucosa and muscularis of the bladder and ureter as well as in the periureteral fat, in the kidney

Fig. 6.—Ureter with no cellular infiltrate; × 130.

pelvis, in the parenchyma of the kidney and its fatty capsule. The lymphatics of the bladder, ureter and kidney have distinct communicating branches, but it is equally important to emphasize the fact that the drainage of the bladder, ureter and kidney is segmental into lumbar and hypogastric nodes and into the nodes along the renal vessels. The ready flow of lymph is not from the bladder through the ureter to the kidney, or vice versa.

Having established the premise that these organs have definite lymphatic systems and that involvement of them by inflammatory exudate has been described by several authors, we will herewith pre-

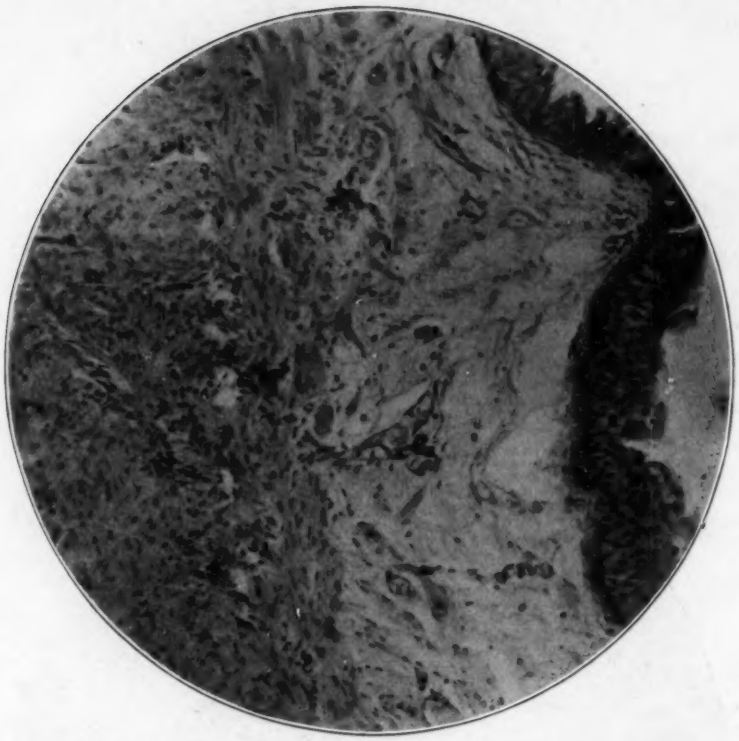

Fig. 7.—Kidney pelvis with no cellular infiltrate; × 130.

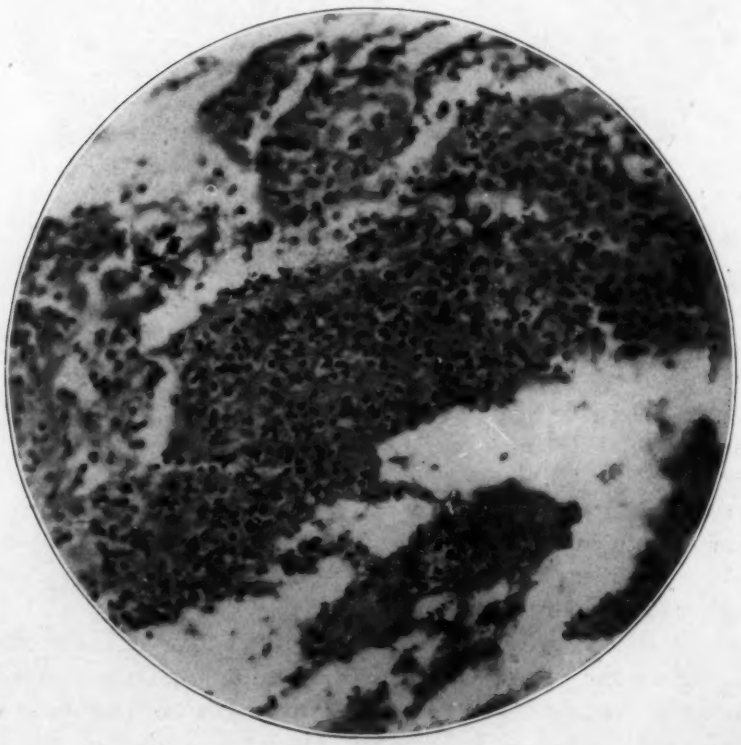

Fig. 8.—Polymorphonuclear exudate on peritoneal coat of the bladder; × 230.

sent our evidence to demonstrate that the occurrence of a cellular exudate in the lymphatics of the ureter and pelvis of the kidney does not necessarily indicate an infection of the urinary stream.

1. *Round-Cell Infiltration in Control Ureters with Sterile Urine.*—Control sections of the ureter in thirty-nine dogs have been studied microscopically, and at the same time the urine has been examined for bacteria by smears and cultures. Cellular infiltration in the lymphatics was absent in fourteen dogs, was present to a limited extent

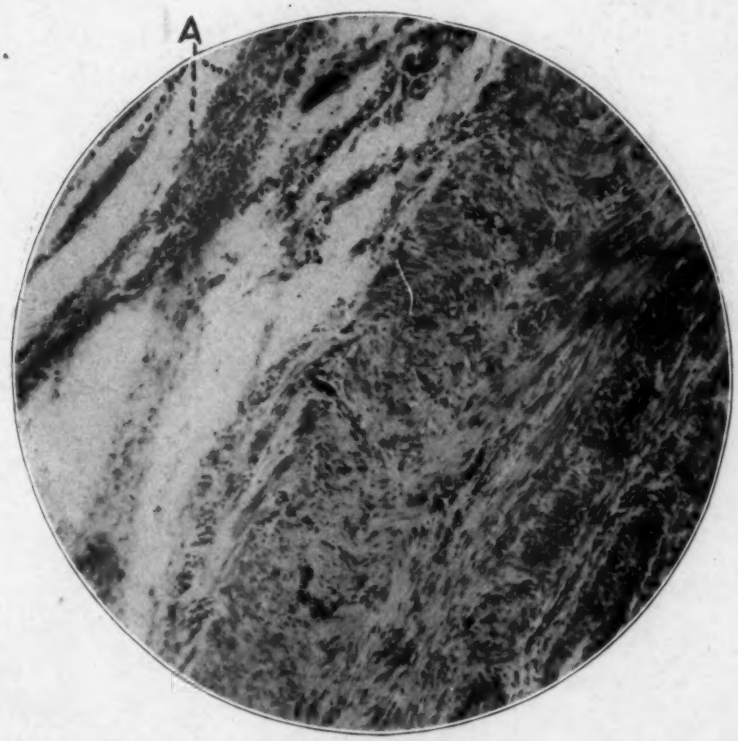

Fig. 9.—Ureter, showing periureteral exudate at *A;* ×90.

in ten, and in five dogs with sterile urine was present to a marked degree (Figs. 1 and 2). In rabbits the presence of round-cell infiltration in the ureter with sterile urine is even more common.

2. *Round-Cell Infiltration of the Ureter with Sterile Urine. Macerated Ureter Sterile.—B. coli* was injected into a dog's bladder, and the dog killed in thirty days. *B. coli* was still present in the bladder urine, but cultures from the ureters and kidney pelves were sterile. Microscopic examination of the tissue revealed a marked round-cell infiltration in the submucosa of the bladder and ureters (Figs. 3 and

4). A section of the ureter, which had been removed under aseptic conditions, was macerated in a sterile mortar, and cultures were made of the tissue extract. These were sterile. This experiment indicates that round-cell infiltration of the ureter is not synonymous with urinary stream infection, and that the presence of round-cell infiltration is not necessarily indicative of active infection.

3. *Ulcerative Cystitis with Ascending Ureteral Infection, but No Infection of the Ureteral Lymphatics or the Blood Stream.*—A num-

Fig. 10.—Polymorphonuclear type of exudate at *A* (Fig. 9); ×230.

ber of experiments on dogs were thus conducted: One ureter was ligated and divided to establish a hydronephrosis which acted as a control on blood stream infection, in which event it became converted into a pyonephrosis; the urethra was partially constricted by a band of fascia, but not sufficiently to prevent urination. *B. coli* was injected into the partially obstructed bladder; ulcerative cystitis developed with ascending infection involving the unobstructed ureter, from which *B. coli* was grown. Microscopically there was no cellular infiltration of any type in the ureteral wall though the bladder wall had a dense polymorphonuclear exudate throughout (Figs. 5, 6 and 7).

It is evident in these experiments that polymorphonuclear infiltration of the bladder does not extend to the lymphatics of the ureter and kidney pelvis with any rapidity, though ascending infection occurs early and readily through the lumen of the ureter.

4. *Cut End of Ligated Ureter Adherent to Infectious Material. Polymorphonuclear Infiltrate of the Periureteral Lymphatics. Hydronephrosis, Sterile.*—A few "happenchance" conditions arose in some experimental work which have a bearing on this problem. After liga-

Fig. 11.—Polymorphonuclear exudate in submucosa of kidney pelvis; × 130.

tion and division of one ureter, some dogs came to necropsy with the peritoneal coat of the bladder covered with a plastic exudate due to accidental infection. To this exudate, the cut end of the ligated ureter was adherent. A microscopic study of the ureter demonstrated a rather marked polymorphonuclear exudate in the periureteral tissue reaching above the ureter to the subpelvic fat. However, in these particular experiments the hydronephrosis that developed above the divided ureter was sterile. A periureteral polymorphonuclear exudate with sterile urine was present (Figs. 8, 9, 10 and 11).

With these experiments in mind it seems clear that involvement of the periureteral lymphatics in round-cell or polymorphonuclear cell infiltration is not synonymous with urinary stream infection. Conversely, urinary tract infection occurs, ascending through the lumen of the ureters without involvement of the ureteral lymphatics.

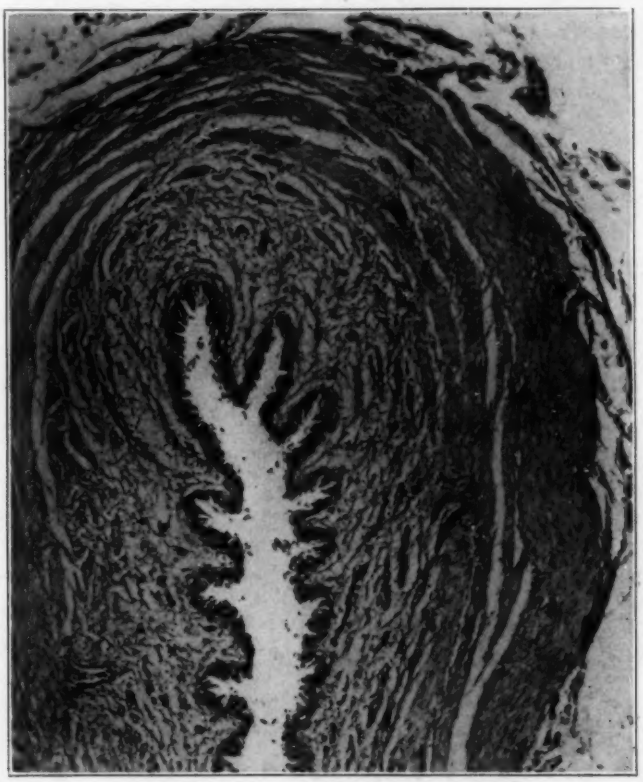

Fig. 12.—Ureter above the gauze showing no infiltrate; × about 70.

URETERAL LYMPHATICS AS A ROUTE FOR EXTRA-URINARY INFECTIONS

The rôle of the lymphatics in conveying infection from the bladder to the ureters and kidneys has thus far been the object of our study. As a corollary, the importance of the ureteral lymphatics in conveying extra-urinary infections to the kidney will be considered.

It is theoretically possible in cases of pyosalpinx, pelvic peritonitis, acute appendicitis or appendiceal abscess that an inflammatory exudate coming in contact with a ureter might involve the periureteral lymphatics of the ureter and eventually spread along them and involve the pelvis of the kidney and kidney itself. This view has been

strongly urged by certain authors to explain the frequency of pyelitis in girl babies whose vaginal secretions have been found to contain *B. coli* soon after birth. In order to consider experimentally these presumptions, the effect of surrounding the ureter in a series of dogs and rabbits with a small piece of gauze impregnated with

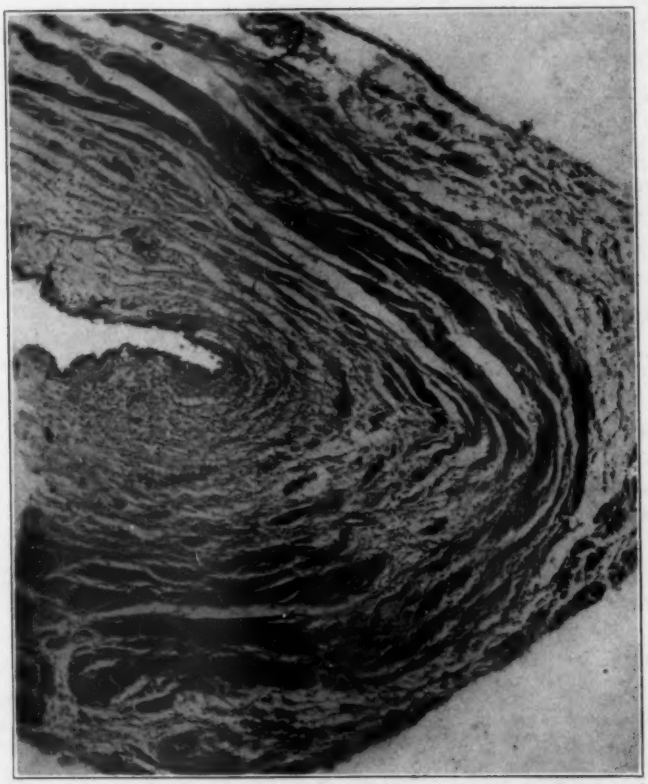

Fig. 13.—Kidney pelvis above the gauze showing no infiltrate; × about 70.

actively growing *B. coli* was studied. This simulates fairly well clinical conditions in which the ureter is in contact with infectious material.

In the first group of rabbits and dogs, a small piece of gauze was drawn under one ureter and saturated with *B. coli* after laparotomy. The opposite ureter was ligated and divided so that the ensuing hydronephrosis would act as a filter for blood stream infection. The control urine, taken before the experiment, was sterile in all of these animals. At postmortem, which occurred from seven to thirty days after the experiment, cultures of urine from both kidneys and bladder were sterile. *B. coli* was grown from the gauze around the ureter. Microscopically, in the region of the gauze, a dense polymorphonuclear

exudate was found around the ureter; but a few centimeters above the gauze, the ureter was free from cellular exudate. Sections of the kidney pelvis and kidney showed no cellular infiltration. On the opposite side, the hydronephrotic kidney and ureter were sterile and showed no cellular exudate (Figs. 12, 13, 14 and 15). The only exceptions to these microscopic findings were in several rabbits in which a few clumps of round cells were found in both kidneys, ureters and bladder. It seems improbable that these cells were related to

Fig. 14.—Ureter below the gauze showing no infiltrate; × about 70.

experimental conditions, as the cellular accumulations were isolated and corresponded to those found in the urinary organs of rabbits under control conditions.

It appears, therefore, that infectious material brought in contact with the periureteral lymphatics does not involve the urinary tract in infection by spreading along the ureteral lymphatics. There was no evidence of ascending infection involving the kidney pelvis or kidney parenchyma, nor was there any descending infection involving the bladder. In a few instances in dogs, the lumbar lymphatic nodes

in the region of the gauze were enlarged and in one instance they suppurated. This is striking evidence of the segmental drainage of the ureter.

In another group of experiments on rabbits and dogs, the ureter was ligated and divided, and the gauze around the ureter, saturated with *B. coli,* was placed near the proximal cut end of the ureter. At necropsy the cut end of the ureter was found embedded in the inflammatory exudate about the gauze. In some of these experiments,

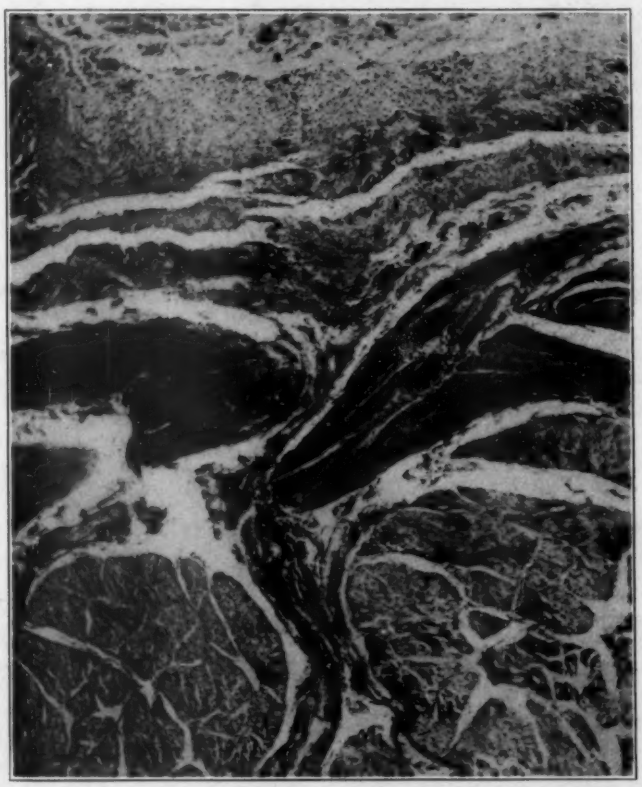

Fig. 15.—Bladder wall with the peritoneal coat showing no infiltrate; × about 70.

the bladder urine and urine from the opposite kidney as well as that from the developing hydronephrosis were infected with *B. coli,* which indicated that a blood stream infection had taken place. On the side of the pyonephrosis, in the submucosa of the kidney pelvis and the ureter as well as in the parenchyma of the kidney, groups of polymorphonuclear cells could be demonstrated microscopically, but there was no characteristic involvement of the spaces about the blood vessels where the larger lymphatics are located.

In other experiments of this type, the urine of the hydronephrosis was sterile as was the urine from the bladder and opposite kidney. There was no involvement of the periureteral lymphatics on the side where the gauze was implanted in the rabbit experiments; but in a few dogs, polymorphonuclear cells were found in the periureteral tissue as high as the pelvis of the kidney.

In experiments on two dogs and one rabbit, with the gauze in contact with the divided ureter, a pyonephrosis was found without periureteral lymphatic or blood stream involvement. The bladder and the kidney urine on the opposite side was sterile. In these instances, the infection probably extended along the lumen of the ureter by direct extension through its cut end.

In those experiments in which a cut end of a ligated ureter came in contact with infectious material, various results were recorded: (*a*) blood stream infection with infection of both kidneys and bladder; (*b*) involvement of the periureteral lymphatics above the point of contact with the infectious material but with no infection of the urinary stream, and (*c*) infection of the hydronephrosis above, with but little or no involvement of the periureteral lymphatics.

In no experiment, however, did it seem probable, after weighing all the evidence, that infection of the hydronephrosis took place by infection traveling along the ureteral lymphatics to the kidney.

CONCLUSIONS

1. Neither round nor polymorphonuclear cellular infiltration of the ureteral or subpelvic kidney lymphatics is synonymous with urinary tract infection, as we regard it clinically.

2. The lymphatics of the bladder and ureter play an unimportant rôle in the conduction of acute infections from the bladder to the kidney.

3. Infectious material brought into intimate contact with the periureteral lymphatics does not affect them to any considerable extent and infection of the urinary stream does not result.

4. An involvement of the periureteral lymphatics may occur when the cut end of a divided ureter, which has been ligated, comes in contact with infectious material; but it is improbable that infection of the kidney pelvis by this route occurs.

NERVE SUTURE

AN EXPERIMENTAL STUDY TO DETERMINE THE STRENGTH OF THE SUTURE LINE *

EDWIN M. MILLER, M.D.
CHICAGO

It is sometimes necessary during the repair of a peripheral nerve injury to resect an extensive scar, even as much as 3 or 4 inches, before reaching normal funiculi, and it is difficult to make an end-to-end suture even when the nerve segments are freely mobilized and approximated by posture. Huber [1] has shown experimentally that end-to-end suture is preferable to any form of transplant, but if a transplant becomes necessary, that taken from the same individual and inserted in the form of a cable is the best. This technic has recently been described by Elsberg [2] and also by Stookey,[3] a large sensory nerve in the neighborhood of the lesion usually being used for the cable. Clinically, this method of repair has not yielded encouraging results, and Lewis [4] attributes this to the tendency of the distal line of suture to act as a block to the regenerating fibers that have successfully traversed the transplant. He is of the opinion that secondary operation in these cases with the removal of the narrow scar at the distal end of the cable and a new end-to-end suture might effectively aid complete regeneration. It would seem wise, then, to employ primarily an end-to-end suture whenever possible, even though extreme flexion is necessary for approximation, but in doing this the question naturally presents itself as to the strength of such a suture line and the length of time necessary to immobilize a limb in flexion before allowing tension on the sutured nerve. This problem has been investigated by us experimentally at the suggestion of Dr. Lewis with the view of establishing a few facts which could be employed in clinical work.

TECHNIC

The first series of experiments included sixteen dogs, eleven of which were free from infection and furnished data for this report. Under ether anesthesia the left sciatic nerve was exposed through

* From the Surgical Department of Rush Medical College.

1. Huber, G. C.: Repair of Peripheral Nerve Injuries, Surg., Gynec. & Obst. **30**:464 (May) 1920.

2. Elsberg, C. A.: Technic of Nerve Suture and Nerve Grafting, J. A. M. A. **73**:1422 (Nov. 8) 1919.

3. Stookey, Byron: The Technic of Nerve Suture, J. A. M. A. **74**:1380 (May 15) 1920.

4. Lewis, Dean: Principles of Nerve Surgery, J. A. M. A. **75**:73 (July 10) 1920.

an incision between muscle planes, the nerve was freed from its bed for a short distance and a section was removed, sufficiently long to necessitate extreme flexion of the leg on the thigh in order to perform an end-to-end suture. The technic of approximation was similar to

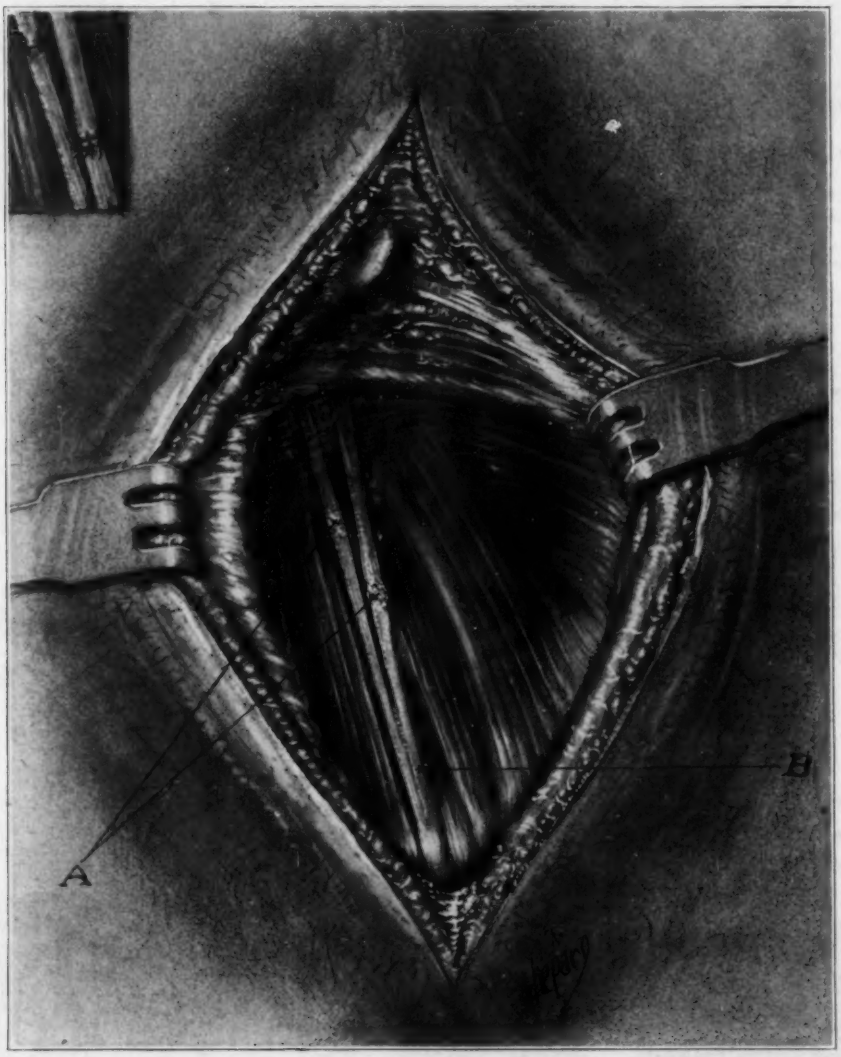

Fig. 1.—*A*, line of suture of posterior tibial and external popliteal nerves on right leg; *B*, location of suture of sciatic nerve on the other leg.

that used and recently described by Elsberg, Huber, Lewis, Stookey and others, namely, interrupted sutures of very fine catgut or silk passed through the epineurium only. A plaster-of-Paris dressing was applied to maintain the flexed position as long as desired.

In this series of animals we noted constantly a smooth fusiform enlargement about 1 cm. long in the region of the suture line. The animals that wore a plaster cast on the flexed limb were not inclined to use the limb actively after its removal, so that the amount of pull

TABLE 1.—Effect of Early and Late Use of Limb on Suture Line

Dog	Duration of Experiment in Days	Number of Days in Cast	Observations	Necropsy Findings
98	11	11	Leg immobilized entire period	Dog died of distemper on 11th day. Wound clean. Anastomosis intact and surrounded by small organizing blood clot. Nerve removed for microscopic study. Fixation in Mueller's fluid
88	19	12	After removal of cast on 12th day has not used leg in walking. Carries it partly flexed most of the time	Dog killed on 19th day with ether. Anastomosis intact. Fusiform swelling about line of suture. Considerable loose adhesions. Fixation in ammoniated alcohol
95	36	13	Dog has used the leg considerably in walking since removal of the cast	On 36th day the dog was killed with ether. Fusiform smooth swelling 1.5 cm. long in region of anastomosis which is intact and clean. Fixation in Mueller's fluid
90	16	16	No use of limb observed after removal of the cast on the 14th day	Dog died on 16th day. Wound clean. Anastomosis intact. Fusiform enlargement 1 cm. long in region of suture line
92	25	18	No use of limb in walking observed after removal of cast	Dog died on 25th day. Nerve dissected from loose adhesions. Area of anastomosis appears as a smooth swelling. Nerve fixed for microscopic study
80	27	20	Dog did not use the limb after removal of the cast	Dog died on 27th day. Wound clean. Nerve dissected from clean bed with few adhesions. Anastomosis intact. Fusiform enlargement for 0.5 cm. on either side of suture line. Fixation in ammoniated alcohol
99	21	21	Leg immobilized entire period	Dog died on 21st day. Wound clean. Nerve dissected out from loose adhesions. Line of suture has not held. Ends separated 1¾ inches. Neuroma on proximal end. Fixation in Mueller's fluid
96	35	24	General condition good but animal has used leg very little since removal of the cast	Under ether the nerve dissected from loose adhesions. Anastomosis
81	33	None	Protective dressing applied after operation. Animal very shortly began using the leg in walking and running	Dog died on 33d day. Wound clean. Nerve removed from clean bed. Very little enlargement in region of anastomosis which is intact. Fixation in ammoniated alcohol
94	37	None	Protective gauze dressing and bandage applied after operation. Within a few days the animal began using the leg. At the end of 14 days there was very active use in running	Under ether the nerve removed from a bed of a few loose adhesions. Fusiform swelling about suture line, which is intact. Fixation in Mueller's fluid
93	38	None	After the wound had healed the leg was used very actively in walking and running. General condition excellent	Under ether the nerve removed. Wound clean. Suture line intact. Fusiform smooth swelling in region of anastomosis. Fixation in Mueller's fluid

on the line of suture was practically negligible. Those, however, that had only a protective dressing on the wound for a few days soon began to use the limb actively in walking or running. In fact, on several occasions while the dogs were running about in the yard, it was difficult to tell, except for the toe-drop, which leg had been operated on. In these animals the amount of pull on the suture line was considerable, even after a very few days. At necropsy, which was performed anywhere from eleven to thirty-eight days after operation, examination of these nerves showed separation at the suture line in only *one* instance (Dog 99). This dog died while the leg was held flexed in a plaster cast, the separation obviously not being due to tension. Aside from this we were unable to detect any difference at the suture line between those held flexed for a period in a cast and those subjected to strain within a few days after operation.

These observations led us to examine more accurately the actual strength of the suture line at different periods, and to determine whether there was any constant relation between the size of a nerve and its tensile strength at the point of suture. The technic employed was the same as that used in the previous series except that a section of the nerve was not removed. In every case simply a protective dressing was applied until the skin had healed, the animal being allowed to use the limb at will. At the end of the desired period, the dog was killed with ether, the sciatic nerve was dissected from its bed and divided 4 or 5 cm. distal to the suture line, the proximal end remaining intact. A pair of curved artery forceps was applied to the cut end of the nerve (Fig. 1), and the handle was fastened to a small stout cord which, after passing up over a pulley, was tied to the top of a bottle. By adding water to the bottle very slowly the weight necessary to break the suture line was determined. As the apparatus remained constant in all the experiments no allowance was made for the actual weight of the cord. The size of the nerve was measured by its diameter in a normal portion proximal to the anastomosis. As the shape of these nerves is somewhat variable, some being almost round and others a little flattened, a measure of the diameter seemed the only fair and practical way of judging the size. The fusiform swelling about the suture line caused almost invariably an increase of from 1.5 to 2 mm. at the point of greatest thickness. In the first five dogs, the sciatic was sutured well above its bifurcation, using both legs. Variations in the diameter were sought by selecting small, medium sized and large animals. We soon observed, however, that the difference in the size of the sciatic nerve was not appreciable, even though that of the animals was considerable.

The strength of the suture line in nerves of the same size, tested at the same length of time after operation, varied considerably in different animals, a fact accounted for readily by the variance in general health and well-being of the dog. In the last six experiments, we sutured nerves of constantly different diameters in the same animal and tested their strength at the same periods after operation. For this purpose we used the sciatic on the left leg and the external popliteal and posterior tibial on the right, inasmuch as measurement of a large number of normal nerves showed that the external popliteal has a diameter of from 1 to 2 mm., the posterior tibial of from 2.5 to 3.5 mm., and the sciatic of from 4 to 6 mm., a ratio of approximafely 1 : 3 : 5. Moreover, the variation in their tensile strengths, as determined by this method, is almost exactly proportional to their diameters.

TABLE 2.—Strength of Normal Nerves of Different Sizes

Nerve	Diameter in Millimeters	Amount of Stretch in 1 Cm. of Nerve	Weight in Gm. to Break the Nerve	Remarks
External popliteal.....	1.5	2.5	2,900	Broke at forceps attachment
Posterior tibial.....	3.0	1.0	3,350	Broke at forceps attachment
Sciatic.....	5.0	1.5	5,450	Pulled out at sacral plexus
			5,540	Broke at forceps hold

It is of interest to consider briefly the histologic picture in the region of the suture line before discussing the effect coincident with the changes on the strength of the suture line. Ranson [5] has beautifully described and illustrated, by means of the pyridin modification of the Cajal silver stain, the steps in the regeneration of a nerve sutured after a cleancut transverse division. Within the first twenty-four hours, there is formed a plastic exudate between the nerve ends. In the distal stump, adjacent to this exudate, is a narrow area in which evidences of an early abortive regeneration are seen, characterized by the formation of many small branches from the axis cylinders, having club shaped end-bulbs. These form a distinct network. Distal to this, degeneration of both medullated and nonmedullated fibers begins at once and progresses rapidly. By the eighth day the neurilemmal cells have increased greatly in size and have formed protoplasmic bands which largely fill up the space formerly occupied by the myelin and axis cylinders. In the proximal stump, a narrow area adjacent to the exudate shows an abortive regeneration similar to that in the distal stump. For a short distance proximal to this is a zone of reaction characterized by a swelling of the nerve fibers and the for-

5. Ranson, S. W.: Degeneration and Regeneration of Nerve Fibers, J. Comp. Neurology **22**:487, 1912.

mation of a neurofibrillar reticulum which fills up the space within the neurilemma. The axis cylinders undergo a retrograde degeneration up to 5 or 10 mm. above the suture line. The new fibers are seen on the eighth day as side branches coming off above the zone of degeneration, multiplying rapidly and growing downward as parallel

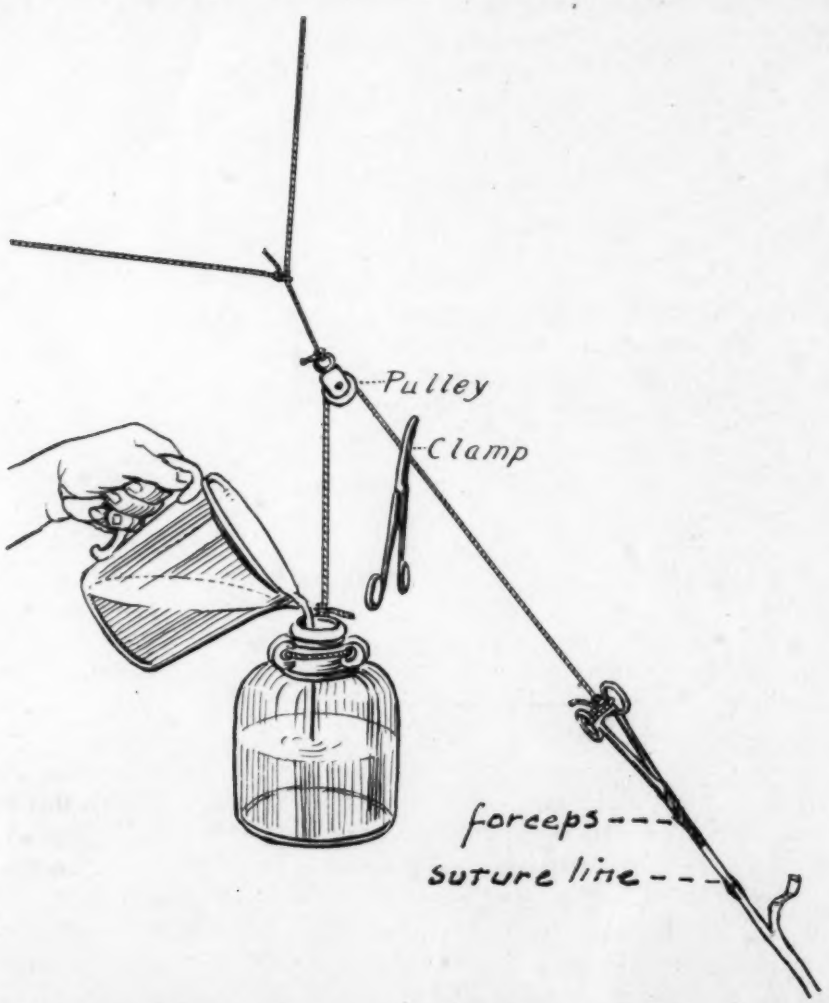

Fig. 2.—Apparatus used to determine the tensile strength of the suture line after end-to-end anastomosis.

bundles within the neurilemma, or spirally to form distinct skeins. When the scar is reached, these new fibers with their terminal bulbs spread in all directions, forming a dense network, the general trend of which is toward the distal stump. By the fourteenth day, a large number of new fibers have bridged the scar and started to grow into

the distal stump, where they are guided by the protoplasmic bands in which they travel. Kirk and Lewis [6] observed similar phenomena after tubulizing with fascia a gap formed by removal of a 10 mm. segment of the sciatic nerve in dogs. They demonstrated that the protoplasmic bands which form bridge the gap within six days and that the regenerated neuraxes from the proximal stump penetrate the distal segment within three weeks.

In the light of the histology of a suture line within the first few weeks after operation, the variations in tensile strength given in Table 3 were determined experimentally.

TABLE 3.—VARIATIONS IN TENSILE STRENGTH

Period after Operation	Dog	Type of Operation: Suture of	Leg	Diameter of Nerve, Mm.	Weight Necessary to Break, Gm.	Remarks
1 wk.	6	Sciatic	Right	4.0	975	Broke at suture line
		Sciatic	Left	—	—	Result not reliable
	30	Sciatic	Right	—	—	Result not reliable
		Sciatic	Left	5.0	430	Broke at suture line
	31	Ext. popliteal	Right	1.5	318	Broke at suture line
		Post. tibial	Right	3.0	—	Accidentally broke
2 wks.	45	Sciatic	Right	5.0	6,327	Broke through line of suture
		Post. tibial	Left	3.0	5,727	Broke through line of suture
	10	Ext. popliteal	Right	1.5	1,665	Threads remained unbroken
		Post. tibial	Right	3.0	2,815	Threads remained unbroken
		Sciatic	Left	5.0	2,615	Broke across suture line
3 wks.	29	Sciatic	Right	2.0	2,885	Broke at suture line
		Sciatic	Left	2.0	1,750	Broke at suture line
	84	Ext. popliteal	Right	1.5	2,215	Broke at suture line
		Post. tibial	Right	2.5	4,800	Pulled out in strands
		Sciatic	Left	4.5	4,950	Pulled out in strands
4 wks.	46	Sciatic	Right	5.0	9,202	Broke at suture line
		Sciatic	Left	5.0	6,342	Broke at forceps attachment
5 wks.	15	Sciatic	Right	1.5	4,675	Broke at suture line
		Sciatic	Left	2.0	4,825	Stitches loose, easily picked out
	80	Ext. popliteal	Right	1.5	2,115	Broke directly across
		Post. tibial	Right	3.0	3,715	Pulled out in long strands
		Sciatic	Left	5.0	5,200	Sutures all loose
	45	Ext. popliteal	Right	2.0	2,615	All stitches loose and easily pulled off before tests were made. These nerves broke directly across suture line
		Post. tibial	Right	5.5	4,850	
		Sciatic	Left	5.0	4,850	

Necropsy Finding: In all of these animals the wounds were clean and very few adhesions were seen about the nerve. There was invariably a fusiform thickening about 1 cm. long in the region of the suture line which increased the diameter about 2 mm.

COMMENT ON RESULTS

The results of the first few experiments were disappointing, as we were not accustomed to the apparatus, and used too heavy a weight in testing the strength of the suture line of three of the animals one

6. Kirk, E. G., and Lewis, Dean: Regeneration of Peripheral Nerves, Bull. Johns Hopkins Hosp. **28**:71 (Feb.) 1917.

week after suture. Later, however, the determinations were easily made. The efficiency of the apparatus used might be questioned in one respect, that of applying forceps to the distal end of the nerve which must of necessity crush the nerve to some extent. This is true, but it did not affect the accuracy of the tests, because, except in a single instance, rupture of the nerve always took place in the region of the suture line. The weight was always increased very slowly and we invariably observed that before rupture occurred the fusiform enlargement increased in length from 1 to 2 mm.

Strength of Suture Line After One Week.—At the end of the first week after suture, the plastic exudate is beginning to organize. There is degeneration of axis cylinders and medullary sheaths in the areas immediately adjacent to the exudate, protoplasmic bands have partly bridged the gap, but the new neuraxes have not as yet penetrated the scar. The weight necessary to separate the two segments at this stage falls below 1,000 gm., the average for nerves of different diameters being 574 gm.

TABLE 4.—Relation Between Size of Nerve and Tensile Strength at Different Periods After Suture

Size of Nerve in Diameter	1 Week	2 Weeks	3 Weeks	4 Weeks	5 Weeks
1.5–2 mm.	318 gm.	1,665 gm.	2,885 gm. 1,750 gm. 2,215 gm.	.....	4,675 gm. 4,825 gm. 2,115 gm.
Average	.....	.....	2,283 gm.	.....	3,357 gm.
3–4 mm.	.....	5,727 gm. 2,815 gm.	4,800 gm.	.....	3,715 gm.
Average	.....	4,271 gm.			
4–6 mm.	785 gm. 430 gm.	6,327 gm. 2,615 gm.	4,960 gm.	9,292 gm. 6,342 gm.	5,200 gm. 4,850 gm. 4,860 gm.
Average	702 gm.	4,471 gm.	.....	7,772 gm.	4,970 gm.

After Two Weeks.—At the end of the second week, a marked change has occurred. The exudate has become a well organized scar, which has increased the diameter of the nerve by about 2 mm. Degeneration in the proximal stump has ceased, and the new neuraxes have not only entered the scar but have formed a dense network there. A few have even penetrated the distal segment. The strength of the suture line has increased enormously. As seen in Table 4 a very small nerve now supports 1,665 gm.; a medium sized nerve on an average, 4,271 gm., and a large 5 mm. nerve, 4,471 gm.

After Three Weeks.—At the end of three weeks the change in tensile strength is less marked. Practically all the new neuraxes have entered the distal segment and have begun their downward growth

within the protoplasmic bands. The strength of the suture line at this period, though not much greater than at the end of two weeks, is becoming more directly proportional to the diameter of the nerve, and the line of separation, instead of always being a cleancut transverse break, is frayed and irregular. The silk stitches have now become less of a factor than in the earlier days. As a rule they can be readily picked off the surface of the scar with forceps.

After Four Weeks.—We should expect from the histology of the changes which have occurred at this time to find the suture line very strong, inasmuch as the scar is completely healed, and made up of cable-like bundles of new, well developed fibers surrounded by organized connective tissue. On Dog 46, a husky animal, a bilateral suture of the sciatic nerve was performed. The right sciatic nerve supported 9,202 gm., while the left nerve broke, not at the suture line, but where the forceps were attached.

After Five Weeks.—At the end of this period the process of repair is complete. The strength of the suture line has now become as great as we should expect it to be even at the end of the sixth, seventh or eighth week. Actually there has been little change in the tensile strengths for the last two weeks, but the direct ratio between the size of the nerve and its strength at the suture line has become better established. What little part the sutures play at this period may be judged from the ease with which they may be removed from the surface.

CONCLUSIONS

1. In dogs, which show individual differences in rapidity of repair as human beings do, the tensile strength of a suture line in the sciatic nerve or its branches is practically as great at the end of the third week as at the end of the fourth or fifth week.

2. The strength of the suture line, especially after the second week, is almost directly proportional to the diameter of the nerve.

3. The epineural sutures of fine catgut or silk play little if any part in the strength of the suture line after the second week.

4. Long defects of nerves may be overcome by mobilization of the segments and posture, an end-to-end suture being performed. The suture line is apparently firm enough after three weeks to begin gradual straightening of the flexed forearm or leg. Clinically after operation upon the sciatic nerve, it would seem best to wait six or eight weeks after suture before extending the leg if flexion has been necessary to complete an end-to-end suture. In case of the median and ulnar, extension of the forearm should not be attempted until after four weeks if flexion has been required.

THE CORRECTION OF SCAR TISSUE DEFORMITIES BY EPITHELIAL GRAFTS

REPORT OF FIVE CASES

EDMUND B. SPAETH, M.D.
Major, M. C., U. S. Army
WASHINGTON, D. C.

In Jaunary, 1920, Col. S. H. McKee, C. A. M. C., published an article on epithelial outlays and inlays in lid repair. Previous to its appearance, one of the patients whose case is reported herewith (Case 2) had already been operated on by free epithelial grafts with unsatisfactory results, prior to his admission to this clinic. Private G. (Case 1) was admitted to this hospital subsequent to the appearance of Colonel McKee's article, and the technic used in the operation in this case was very similar to that suggested by Colonel McKee and by Gillies of Queen's Hospital. The results obtained in the cases here reported were very satisfactory from a functional as well as from a cosmetic standpoint.

REPORT OF CASES

CASE 1.—Private G., aged 23, was admitted to the hospital April 18, 1920. Physical examination was negative except for the eye condition. Vision in the right eye was 20/200, amblyopia exanopsia, and in the left eye, 20/40. The left eye showed a complete ectropion of the upper lid from loss of all tissue, because of a third degree burn, causing scar tissue contraction. The palpebral conjunctiva was deeply ulcerated, in addition to some ulceration of the corneal conjunctiva, i. e., keratitis e lagophthalmo (Fig. 1). The cause of the condition was a third degree burn resulting from the explosion of a gasoline torch four months prior to admission. Under local anesthesia, procain 0.5 per cent. and epinephrin 1:25,000, an incision was made in the upper lid, and the lid margin was allowed to drop to its normal level (Figs. 2 and 3). The edges of the incision were undermined with great care to prevent any destruction of the remaining fibers of the levator palpebrae and its nerve supply. The ulcerated area in the palpebral conjunctiva was completely excised and a very thin, small pedicle flap from the edge of the incision was turned in to cover this raw area (Figs. 4 and 5). A Thiersch graft was cut from the inner aspect of the arm under procain anesthesia (Fig. 6) and wrapped with its epidermal surface internally around a gutta-percha mold. This gutta percha had been sterilized by boiling, then had been softened by hot water after cooling after which the mold had been shaped to fit the cavity formed by the dissection (Figs. 7 and 8). This mold with the graft was then sutured in place (Fig. 8), and the operative field was dressed with warm

1. McKee, S. H.: Arch. Ophth. **49**:30 (Jan.) 1920.

salt solution for the first twenty-four hours, following which, dry dressings were used. Both eyes were bandaged for three days. At the end of six days, the sutures were removed, the line of incision was reopened, the mold was removed and the pedicle of the flap to the palpebral conjunctiva was resected. A small amount of serum had formed at the site of this outlay, so that the mold was removed without any difficulty. In fact, the mold was

Fig. 1 (Case 1).—Scar tissue ectropion from loss of tissue of the upper lid with ulceration of the everted palpebral conjunctiva.

Fig. 2 (Case 1).—Line of incision made to allow lid margin to drop to its normal level.

apparently floating in position. No infection of any kind was present. Dry dressings were continued for two weeks, after which careful massage of this new upper lid was instituted. Immediately following the removal of the mold, the condition was over-corrected at least 50 per cent. Massage and the contraction that always follows Thiersch graft outlays soon brought the lid to normal size and position. The normal amount of movement in the new lid was most gratifying. One month following the Thiersch graft, two small free

grafts, about 1½ inches in length and one-fourth inch in width, were excised from the occipital scalp and placed in the supra-orbital region to replace the loss of the eyebrow. The artist has represented these as a solid Wolf graft in the illustration; but this is an error. The grafts were placed parallel within the skin with all fat tissue attached. A bridge of about one-fourth inch of normal skin intervened (Fig. 9). The condition, Aug. 20, 1920, when the patient

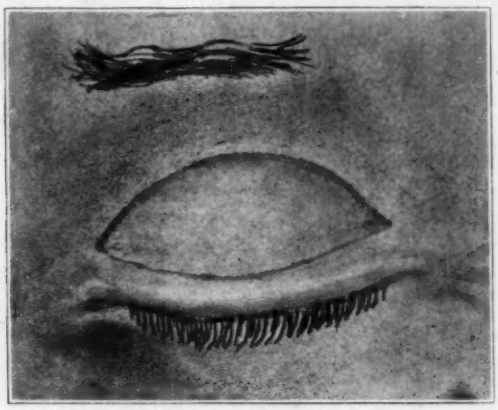

Fig. 3 (Case 1).—Lid margin released by dissection down to its normal level.

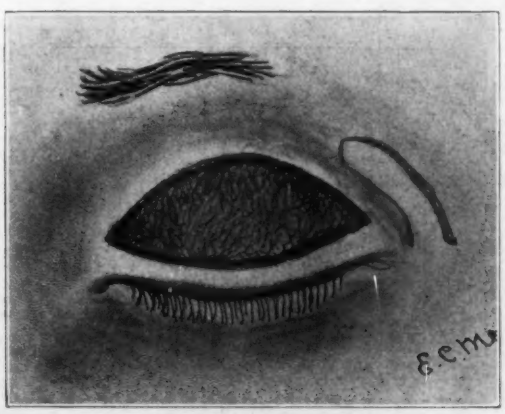

Fig. 4 (Case 1).—Line of incision to prepare pedicle flap for replacement of ulcerated conjunctiva.

was discharged from the hospital, leaves nothing to be desired. The pedicle flap thickened the upper lid to some extent, but not enough to cause concern. The keratitis e lagophthalmo was cured coincident with the removal of the mold and release of the upper lid. No further treatment for this complication was necessary.

Case 2.—Lieutenant J, aged 29, was admitted August, 1919. Physical examination was negative with the exception of that of the eyes and one ear, as well as a deformity of the skin over the bridge of the nose. The ear condi-

tion was a marked deformity and decrease in the size of the concha from scar tissue contraction with loss of substance. The eye condition was a bilateral scar tissue contraction ectropion of both the upper and lower lids. The causative agent in this case was a third degree burn from a phosphorus grenade explosion. The first operative work done on this patient was the taking of a pedicle flap from the forehead to repair the deformed skin over the bridge of

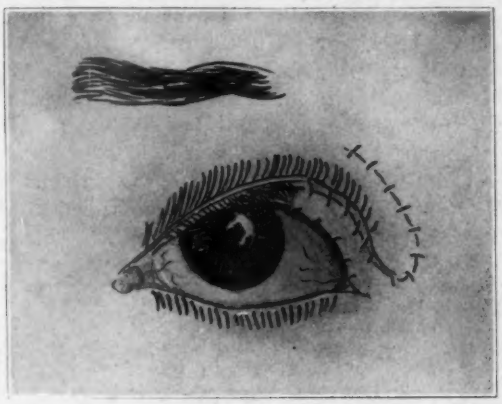

Fig. 5 (Case 1).—Pedicle flap in place.

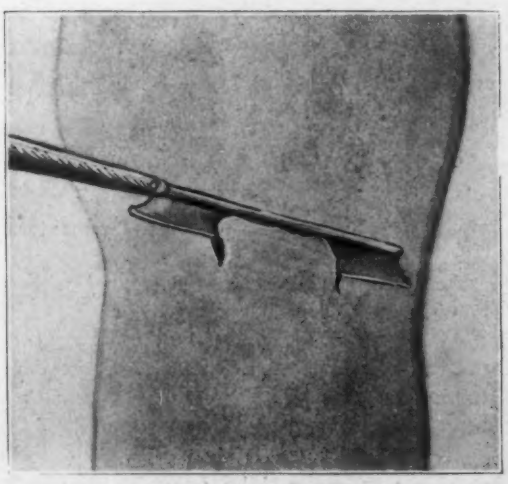

Fig. 6.—Thiersch graft cut from the inner aspect of the upper arm.

the nose. The condition was overcorrected to form a slight epicanthus. The next procedure was a plastic repair of the ear by pedicle flaps from the neck, and cartilage implants taken from the seventh costal cartilage. The results of these operations were satisfactory, but are not being considered in this paper. The condition of the left ear and the forehead is illustrated in Figure 10, which also illustrates the ectropion with lagophthalmus. Using the same procedure as in Case 1, and under the same anesthetic, an incision and a wide

dissection of both the upper and lower lids was performed, sufficiently extended to release the lid margins and bring them into an overcorrected position. Molds of sterile gutta percha were formed to fill the cavities caused by the relaxation of the lid margins to their normal positions (Fig. 11). The musculature and its nerve supply was carefully conserved in the dissection. Thiersch grafts were cut from the inner aspect of the arm, under procain and epinephrin and were wrapped around these molds. The molds were then sutured in place. The sutures and molds were removed the sixth and seventh days. The movement present in the reconstructed lids was of normal range. A month later the same type of Wolf graft was inserted into the supra-orbital region for the formation of a new eyebrow (Fig. 12). In this case as in the first case, the Thiersch graft dressing for the first twenty-four hours was saturated with warm physiologic sodium chlorid solution every four hours. Both eyes were bandaged for the first four days. In this case the repair of both the upper and lower lids of one eye was completed at one time. A subsequent operation was performed at the end of three weeks on the other eye.

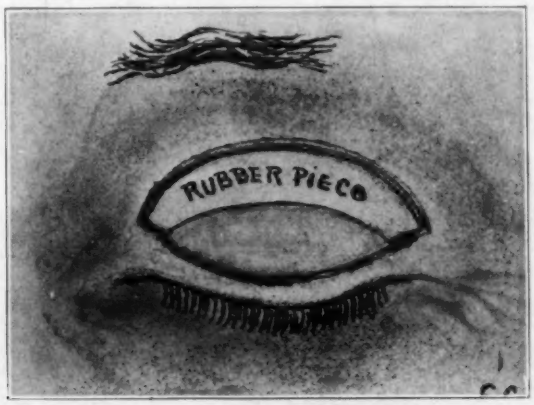

Fig. 7 (Case 1).—Fitting of gutta-percha mold in place.

The dressing for the Wolf graft also was saturated with warm physiologic sodium chlorid solution every four hours, and was continued for three days. Very few sutures were used in the placing of the Wolf graft.

The other three cases in this series are scar tissue deformities resulting from gunshot wounds about the eye.

Case 3.—Private S., aged 21, was admitted in October, 1919. Examination disclosed traumatic enucleation of the left eye with almost entire absence of a conjunctival sac. This was replaced by an unhealthy mass of granulations with some entropion of both upper and lower lids. Granulations and superficial infection cleared up under treatment with silver nitrate, dressings of surgical solution of chlorinated soda (Dakin's solution and packing the socket with gauze impregnated with a boric acid petrolatum ointment (U. S. P. Boric Acid Unguentum). Under general anesthesia, a deep incision was made posterior to the upper and lower lids. The line of incision followed that of the normal conjunctival culdesac. A sterile gutta-percha mold was fitted and wrapped with a Thiersch graft. The mold was made with an upper and lower half accurately fitted to facilitate the removal of the latter. The entire

cavity of the socket was freely curetted, and the mold with the graft was placed in position. The lid margins were freshened by excision of a very thin line of tissue and were then sutured together. Six days later, the mold was removed and a glass ocular prosthesis was furnished from the stock of standard reform eyes in the clinic.

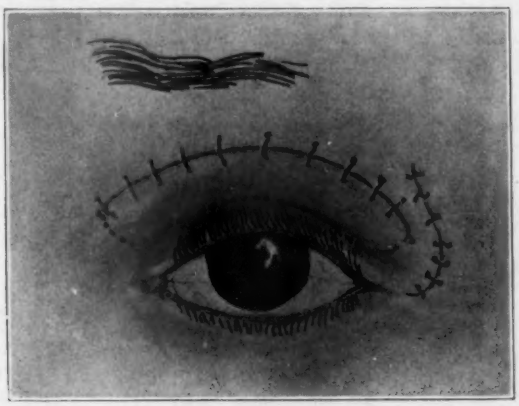

Fig. 8 (Case 1).—Sutures completed.

Fig. 9 (Case 1).—Final result of Thiersch graft and position of Wolf graft for repair of eyebrow.

CASE 4.—Private M., aged 27, was admitted in March, 1920. Examination revealed traumatic enucleation of the right eye with loss of bony tissue from the outer inferior edge of the supra-orbital area. The bony defect was 1 inch long and one-half inch in width. The skin over this area was adherent to the site of the bony defect, drawing the upper lid upward and outward. The upper lid was fixed, making all motion of it impossible and preventing the socket from retaining an ocular prosthesis. Under procain and epinephrin anesthesia, a skin incision was made below the supra-orbital margin, and by deep

undercutting, complete release of the upper lid was obtained. A very large cavity resulted. A mold of sterile gutta percha was fitted, wrapped with a Thiersch graft from the arm, and was sutured into the cavity made by the dissection.. Six days later, the sutures were removed with the mold. At the time of removal of the sutures, some slight suppuration had formed inside the closed cavity without harming the graft in any way. The operation was satisfactory in so far as it furnished sufficient skin to relax the epidermal defect. One month later under general anesthesia, the bony defect was corrected with a cartilage implant. Cartilage was obtained from the seventh costal cartilage and was cut slightly oversize, but conformed to the shape of the defect. This was mortised into position immediately beneath the Thiersch graft. When dressings and sutures were removed, it was found that the last procedure had completed the correction of the original condition. The bony defect was filled in and the skin lay smoothly over its former position. The

Fig. 10 (Case 2).—Condition of the left ear and forehead.

lid was entirely relaxed. With the addition of a small canthoplasty which is to be performed at an early date, the socket will be in proper condition for the fitting of a glass eye.

Case 5.—Private D., aged 19, was first seen in October, 1919. Examination revealed traumatic enucleation of the left eye with an ectropion and contraction of the upper left lid, upward and outward. The cause of the deformity was the loss of soft tissue with a much contracted scar adherent to the outer edge of the supra-orbital region. The socket was able to hold a glass eye fairly well. Because of the poor cosmetic result, however, the patient refused to appear outside the hospital ward with his left eye uncovered. Under procain and epinephrin anesthesia, a horizontal incision was made through the center of the scar. By undercutting, complete relaxation was obtained above and below the incision. A sterile mold of gutta percha was fitted slightly oversize, wrapped with a Thiersch graft and sutured into the cavity. Six days later the sutures were removed. The result was entirely satisfactory to the patient as well as to the operator.

COMMENT

These cases are not unusual, nor should the results be considered extraordinary. Colonel McKee mentioned one thing that I must repeat because it is very important: "It is essential that the cavity be

Fig. 11 (Case 2).—All lid margins at their normal level as a result of incision and dissection, as illustrated by Figure 3.

Fig. 12 (Case 2).—Completed result: normal motion in lids, ectropion cured and the Wolf graft in position.

made much larger than thought necessary. It will undoubtedly shrink some." In the fourth case of this series, the cavity made by the dissection was so large that if it had not been for the fact that I wanted

an excess of skin because of the cartilage implant that I planned to place subsequently, the result would have been a depression covered by a graft.

In work of this type, all scar tissue must invariably be released. In working on the lids, the undercutting should be close to the undersurface of the skin to save every fiber of muscle tissue remaining. It was found that from six to eight days was long enough for the mold to stay in the cavity. If it is not removed by that time it is almost certain to break out through the line of sutures, and the result is a ragged, puckered, uneven Thiersch graft and skin junction.

Fine black silk sutures were used in all the cases. It will be found that the original deformity will be present and exaggerated until the removal of the molds. This should, however, cause no alarm. As far as my experience goes, there is no reason why all pure Thiersch graft outlays cannot be performed under local anesthesia. A half of 1 per cent. procain with epinephrin, 1-25,000, is advised both for the dissection and for the cutting of the graft. No ill effects have followed this practice. Thiersch grafts should be cut as thin as possible.

These cases are selected to show what may be expected from the use of epithelial grafts.